# King Fahd University of Petroleum & Minerals Computer Engineering Dept

COE 543 – Mobile and Wireless Networks

Term 022

Dr. Ashraf S. Hasan Mahmoud

Rm 22-148-3

Ext. 1724

Email: ashraf@ccse.kfupm.edu.sa



# Lecture Contents

1.

# Main References

- K. Pahlavan and P. Krishnamurthy, A Unified Approach: Principles of Wireless Networks, Prentice Hall, 2002 – Section 6.4
- J. Wilkes, "Privacy and Authentication Needs for PCS," IEEE Personal Communications, August 1995, pp. 11-15
- J. Williams, "The IEEE802.11b Security Problem, Part 1," IT Professional, November-December 2001, pp. 91-95 (and the references therein)



# Wireless Media

- RF is a shared media
  - Wireless communication is more susceptible to eaves dropping
- No privacy
- The presence of the communication request does not uniquely identify the originator
- Need for Privacy and Authentication

## None Cryptographic Means

- Number Assigned Module (NAM) and Electronic Serial Number (ESN)
  - Used for authentication
- Using the > 900 MHz band
  - Outside the range of typical scanners
- Which is more secure FDMA, TDMA, or CDMA?
- None cryptographic methods usually do not provide the proper solution



http://www.philzimmermann.com/

## Levels of Privacy

- Level 0: None – with no privacy enabled
  - Anyone with digital scanner can monitor calls
  - A "lack of privacy" indicator should be provided – a public trust issue
- Level 1: Equivalent to Wireline
  - Most people assume wireline calls are secure – eaves dropping can be detected – not as in wireless
  - Used for routine every day calls
  - Would take a year or so to break encryption – would require same effort to break every call
- Level 2: Commercially Secure
  - For proprietary info
  - Would take 10~25 yrs to break encryption – would require same effort to break every call
- Level 3: Military/Government Secure
  - None breakable?

## Privacy Requirements

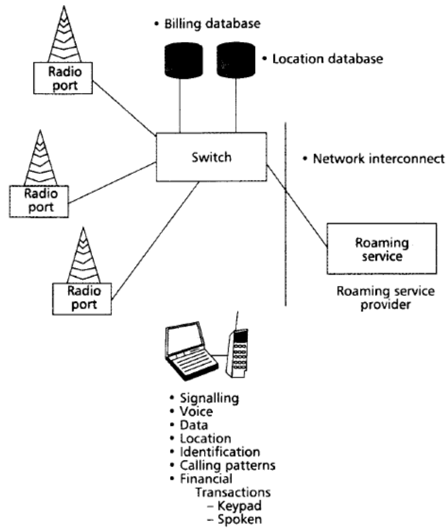
- Privacy of Call Setup Information
  - Calling #, calling card #, type of service, etc.
- Privacy of Speech
  - Must be encoded and none interceptable
- Privacy of Data
  - Must be encoded and none interceptable
- Privacy of User Location
  - Location should not be disclosed – encrypting user id
  - Remember HLR and VLR have this info – must not be subject to attacks



## Privacy Requirements – cont'd

- Privacy of User ID
  - User ID may be encrypted
  - Prevents analysis of calling patterns for this ID – VERY IMPORTANT
- Privacy of Calling Patterns
  - No info sent from mobile should allow traffic analysis
  - This info: calling #, frequency of use, caller identity
- Financial Transactions
  - Visa card # or bank transactions over the air!!
  - Securing the DTMF

## Privacy Requirements






## Theft Resistance Requirements

- Cryptographic design should make the reuse of stolen personal terminal difficult
  - Even if registered to a new legitimate account
- Clone Resistant Design
  - Mobile unique info must not be compromised
    - Over the air – eaves dropping
    - From the network – secure databases
    - From network interconnect – info passed between systems for security checking of roaming mobiles must have enough info to authenticate the mobile and not enough info to clone it!!
    - From users cloning their own mobiles

## Theft Resistance Requirements – cont'd

- Installation Fraud
  - Cryptographic system must be designed to that installation cloning is reduced or eliminated
- Repair Fraud
- Unique User ID
  - Identify the correct person using the mobile for billing purposes
- Unique mobile ID
  - Different than user ID
  - Smart card or PCMCIA card containing all security info



## Radio System Requirements

- Multipath Fading
  - Immune to sever burst errors
- Thermal Noise/Interference
  - The modulation scheme and the cryptographic system must be designed so that interference with shared users of the spectrum does not compromise the security of the system
- Jamming
  - Should work in the face of jamming – does not break
- Support for Handovers

# Other Requirements

- Lifetime of ~20 years:
  - An algorithm that is secure today may be breakable in 5 to 10 years
- Physical Requirements:
  - Mass production
  - Exported and Imported
  - Minimal impact on handset size, weight, power consumption, etc.
  - Low-cost Level 1 implementation



# Other Requirements – cont'd

- Law Enforcement Requirements
  - With the right court order, the law enforcement should be able to tap into the wireless calls
  - Over the air:
    - No encryption – easy
    - Breakable encryption
    - Strong encryption – problematic – need to obtain key
  - Wiretap at switch:
    - Preferred method – easiest

## Network Security - Services

- (Def): Specific measures employing security mechanisms that combat security attacks on a network
- Include:
  - Confidentiality or Privacy: resistance to interception
  - Message Authentication: integrity of message and a guarantee that the sender is who he/she claims to be – Attacks: message modification or impersonation of sender
  - Nonrepudiation: service against denial by either party of creating or acknowledging a message – similar to digital signatures based on public key encryption – Attacks: fabrication
  - Access Control: only authorized entities can access – Attacks Masquerading
  - Availability: access to resources is not prevented by malicious entities (remember www.aljazeera.net!!) – Attacks: denial of service

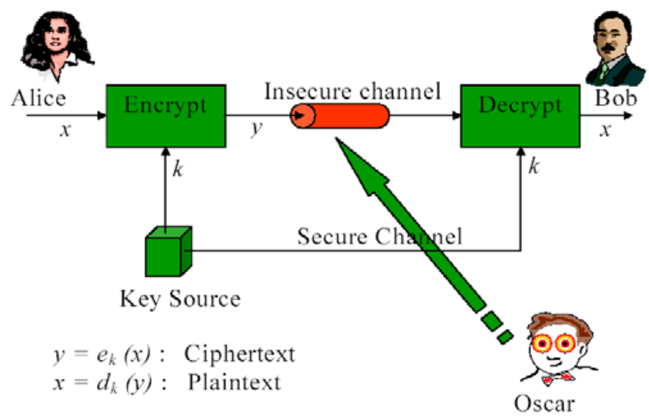


## Privacy

- Encryption
  - one way of providing most of the previously listed services
  - SHOULD be computationally secure – non breakable ideally
- Terms:
  - Message – plaintext or cleartext
  - Encoded version – ciphertext
  - Key – k
- Time and Cost to break the scheme should be significant relative to protected value
  - Should assume interceptor has access to plaintext-ciphertext pairs

# Conventional Encryption Model

- Secret-Key Algorithm



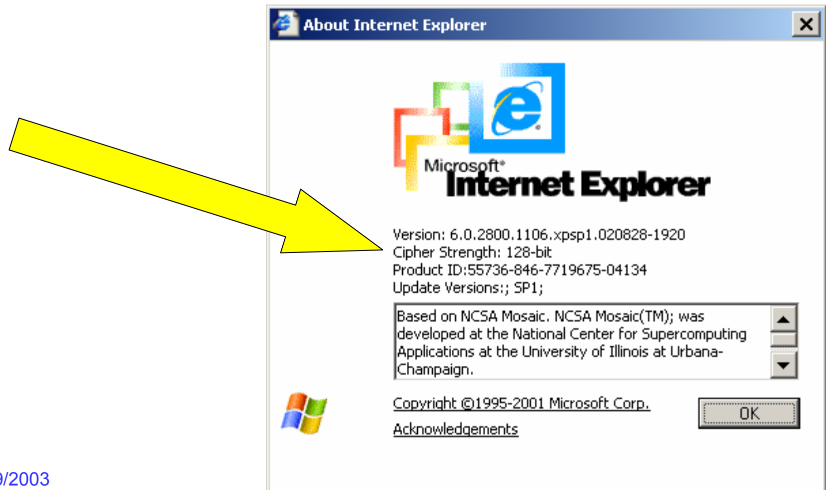



# Date Encryption Standard (DES)

- A symmetric key algorithm
  - Key used for encryption is the same as that used for decryption
- Two Principles:
  - Confusion ←→ scrambling of original data
  - Diffusion ←→ creating randomness – can not relate changes to plaintext to those of ciphertext
- Most secret-key algorithms are unbreakable except by brute-force
  - Key length of n bits → at least $2^{n-1}$ steps to break encryption
- Main advantage – fast; appropriate for fast data streams
  - Compared to public-key algorithms

## Date Encryption Standard (DES) – cont’d

- Usually a key size of 128 bits is recommended



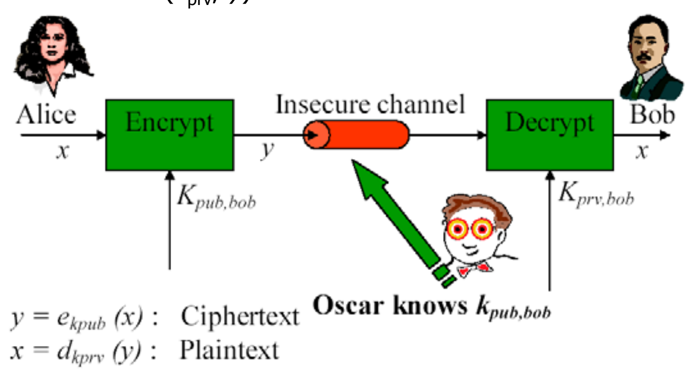



## Public-key Algorithms

- Every pair of users have to have a key
  - A network of N users require the distribution of N(N-1)/2 keys!
  - Large and impractical for large N
- Key distribution schemes:
  - Needham-Schroeder
  - Kerberos
- Concept introduced by Diffie and Hellman in 1977

# Public-key Algorithms – cont'd

- It is extremely easy to compute $y = f(k_{pub}, x)$
- Given $k_{pub}$, and $y$, it is computationally not feasible to determine $x = f^{-1}(k_{pub}, y)$
- With a knowledge of $k_{prv}$ that is related to $k_{pub}$, it is easy to determine $x = f^{-1}(k_{prv}, y)$






# Public-key Algorithms – cont'd

- f ~ belongs to a group of functions referred to

as a trapdoor one-way function - e.g. factorization problem and discrete logarithm

- Since $k_{pub}$ is available and the method is based on a mathematical structure ➔ need to be 3 to 15 times larger than the secret-key counter parts
- Elliptic Mathematics (refer to: http://world.std.com/~dpj/elliptic.html) provides a mean to use smaller keys with same level of secuirty

## Public-key Algorithms – Examples

- Rivest-Shamir-Adelman (RSA)
  - Employs integer factorization
  - Most popular
- Diffie-Hellman key-exchange
  - Based on discrete logarithm
  - Wireless networks
  - Used for key exchange for web transactions, e-commerce, IP security.
  - See appendix 6A for details
- Digital Signature Standard (DSS)
  - Based on discrete logarithms



## Public-key Algorithms – Characteristics

- Computationally intensive
- Encryption rates quite small
- Rarely used for bulk data transfer
- Usually used to exchange a *session* key – to use a secret-key algorithm for later communications
  - Different session key each time!

## Cost Equivelant Key Lengths (in Bits) of Various Encryption Schemes

| Secret-key Algorithm | Elliptic Curve | RSA | Time to Break | Memory |
|---|---|---|---|---|
| 56 | 112 | 430 | Less than 5 mins | Trivial |
| 80 | 160 | 760 | 600 months | 4 Gb |
| 96 | 192 | 1,020 | 3 million years | 170 Gb |
| 128 | 256 | 1,620 | $10^{16}$ years | 120 Tb |



## Block vs. Stream Ciphers

- Block Ciphers – DES and Advanced Encryption Standard (AES)
  - Encrypt blocks of data at a time
  - Requires buffering and padding
- Stream Ciphers – no need for buffering
  - More suitable for a jitter-sensitive service
  - Usually a simple XOR operation is used
- Example:
  - IEEE802.11 employs the encryption algorithm RC-4 to generate a pseudorandom key stream using a 40-bit master key and an initial vector (IV)
  - Data is simply XORed with the key to create ciphertext

## Message Authentication

- Involved:
  - Sender authentication
  - Message integrity
- This is accomplished using a message digest (MD) and a message authentication code (MAC)



## Message Authentication Code (MAC)

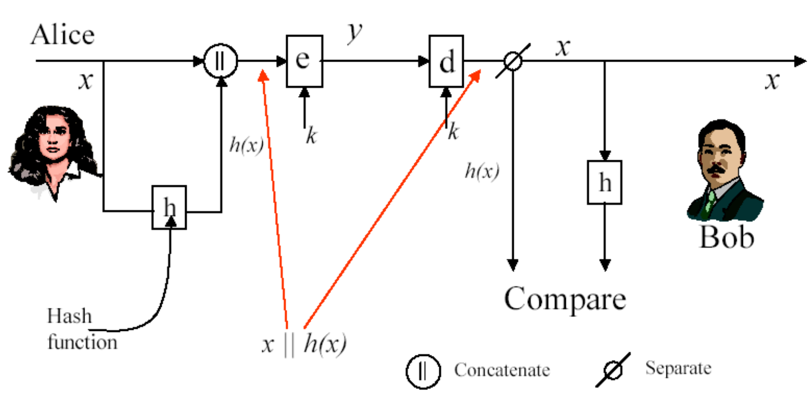
- MAC creates a fixed-length sequence of bits that depend on the message and the secret key
  - Not a function of message size
  - It is computationally infeasible to generate the MAC without the original message and key
- Message is then delivered (with the MAC) to destination
- Receiver computes MAC again based on received message
- New MAC is equal to old MAC IFF message was not tampered with (remember secret key is a secret!)

## Message Digest (MD)

- MD depends only on the message x
- A hash function, h, is used to create the MD, h(x)
- The MD is appended to the message x ➔ x || h(x)
- The newly overall message x || h(x) is encrypted using the secret-key
- h(x) has to be sufficiently long
  - For a b bit h(x) ➔ a fake message with same h(x) can be generated in $2^{b/2}$ trails



## Message Authentication with Hash Functions




What is a hash function?
Refer to http://www.rsasecurity.com/rsalabs/faq/2-1-6.html

## MD and HMAC C++ code

- From http://njet.org/doc/Doc/$24$24native/anvil/crypto.html
- **Message Digest (MD)** provides applications the functionality of a message digest algorithm, such as MD5 or SHA. Message digests are secure one-way hash functions that take arbitrary-sized data and output a fixed-length hash value.
- **Message Authentication Code (MAC)** Since everyone can generate the message digest, it may not be suitable for some security related applications. Because of this, Anvil+ also supports HMAC (rfc2104), which is a mechanism for message authentication using a (secret) key. So you can use a key with a hash algorithm to produce hashes that can only be verified using the same key.

+ Anvil is a crypto library that can create message hash codes or checksums from any data. It is posted on the webpage listed above.



## Identification Schemes

- Need:
  - Access to an automatic teller machine
  - Logging on to a computer
  - Identifying a user of a cellular phone
  - Etc.
- Identification = entity authentication
  - A password or a pin compared to a securely stored hash value
  - Susceptible to replay attacks if transmitted over-the-air in an insecure manner
- Challenge-Response identification or Strong identification
  - Used in wireless networks

# Identification Schemes – cont'd

- A nonce: a value employed no more than once for the same purpose
  - Eliminates *replay* attacks

Example:

1. Consider an IS-136 digital TDMA network
2. The network (BSS) generates a random # RANDU and sends it over the air to mobile
3. Mobile computes a value AUTHU using the encryption algorithm Cellular Authentication and Voice Encryption (CAVE)
4. AUTHU is sent to network and compared with a computed version at the network
5. If the two AUTHU match ➔ the mobile is authenticated – using IS-41 terminology



# Identification Schemes – cont'd

Example: Challenge-Response mechanism in IS-41

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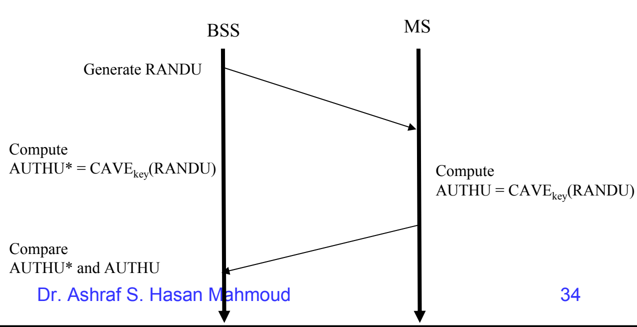


# IEEE802.11 Security & Privacy

- Objectives:
  - To provide a wired equivalent privacy (WEP)
  - To protect against
    - Eavesdropping
    - Unauthorized access

1. http://www.cs.umd.edu/~waa/wireless.html and the references therein especially the following paper: "Your 802.11 network has no clothes,"
2. http://www.mobileinfo.com/Security/index.htm



# MAC Frame Format

- General MAC frame format & Control Field
- WEP = 1 ➔ data bits are encrypted (refer to chapter 11 of Pahlavan)

| frame control (2) | duration ID (2) | address 1 (6) | address 2 (6) | address 3 (6) | seq control (2) | address 4 (6) | frame body (0-2312) | CRC (4) |
|---|---|---|---|---|---|---|---|---|

in bytes

| Protocol Version (2) | Type (2) | Subtype (4) | To DS (1) | From DS (1) | More frag (1) | Retry (1) | Pwr Mgt (1) | More data (1) | WEP (1) | Rsvd (1) |
|---|---|---|---|---|---|---|---|---|---|---|

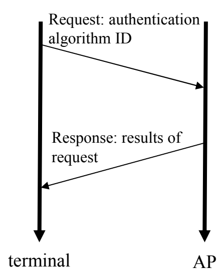
in bits

## Authentication Schemes for IEEE802.11

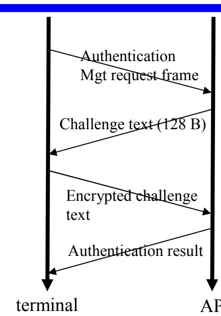
- Three schemes:
  1. Open system authentication
     - Default – uses SSID as a password to gain acess
     - NULL Authentication function – authenticates anyone requesting authentication
     - Not secure
  2. Shared key authentication (WEP based)
     - 40-bits key
     - Not very secure
     - Standard does not specify key management or where to get this key from!!
     - Optional
  3. Access Control List (MAC address filtering)
     - MAC address based
     - Not scalable – requires manual setting
- Not available for ad-hoc



## Authentication Schemes for IEEE802.11




Open System Authentication

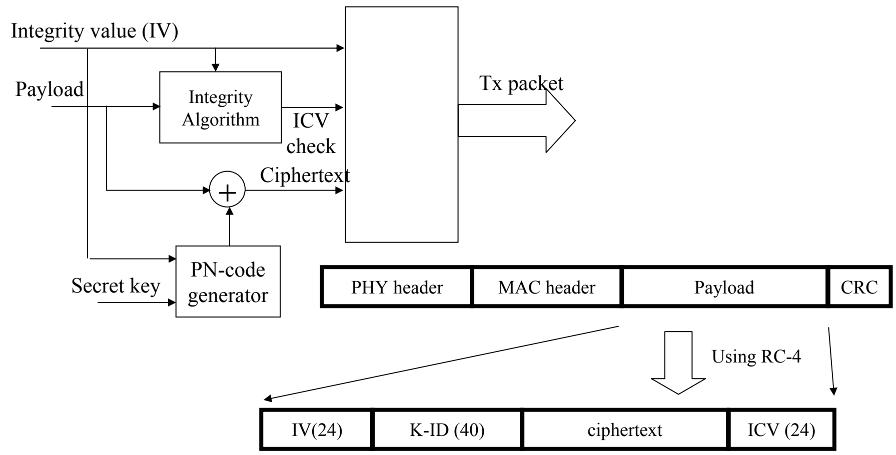



Shared-key Authentication

Challenge text: The challenge text is generated by using the WEP pseudo-random number generator (PRNG) with the "shared secret" and a random initialization vector (IV)

Challenge response: encrypted with WEP using the "shared secret" along with a new IV

# Privacy in IEEE802.11




Note that the IV and the key-ID are sent in the clear!
Same shared key for uplink and downlink



# RC4 Encryption (Stream Cipher)

- *Reasonable* strong:
  - A brute force attack on this algorithm is difficult since every frame is sent with a different IV
  - IV restarts the pseudo random number generator (PRNG) for each frame
- Self-Synchronizing:
  - Even if some intermediate frames are lost, the WEP algorithm resynchronizes at each frame

## Encryption Keys

- Window of four keys
  - Can be manually configured – up to four keys
  - Each is 40 bits (5 ascii or 10 hex digits)
  - For all network
- Key-mapping table
  - Each unique MAC address has separate keys – one per device
  - Need to be configured manually
  - Most secure