HICCUPS: Hidden Communication System for Corrupted Networks

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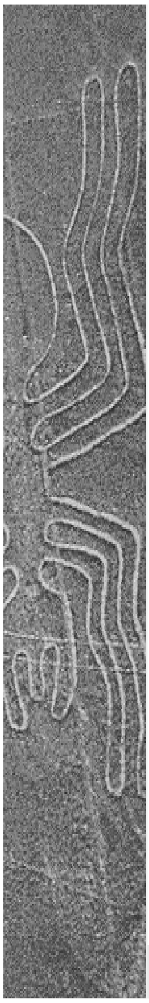


Outline

- Historical background
- Related work
- HICCUPS concept
- Network environment for HICCUPS
- Hidden data channels
- HICCUPS operation
- Functional parts of HICCUPS
- Example of implementation framework for wireless local area networks (WLAN) IEEE 802.11

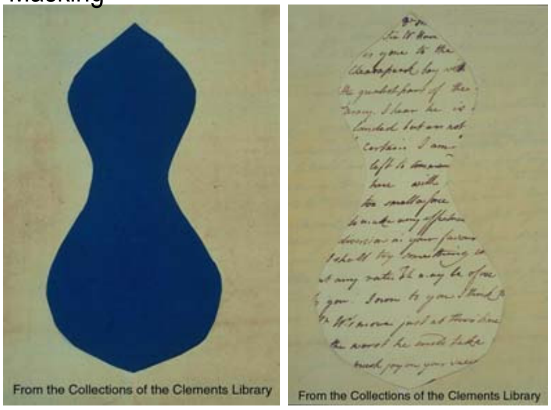
HICCUPS

- **HICCUPS** =
  HIdden **C**ommuni**C**ation system for corr**UP**ted network**S**
- Original network steganographic system for shared medium networks developed at Warsaw University of Technology, Poland – Polish patent pending P.359660
- **hiccup** (Merriam-Webster dictionary)
  Variant: *also* **hiccough**
  - *noun*
    1 : a spasmodic inhalation with closure of the glottis accompanied by a peculiar sound
    2 : an attack of hiccuping - usually used in plural but singular or plural in constr.
  - *intransitive verb;* inflected forms: **hiccuped** *also* **hiccupped**; **hiccuping** *also* **hiccupping**
    : to make a hiccup; *also* **:** to be affected with hiccups

Historical Background

Human vs. Human Problem

Masking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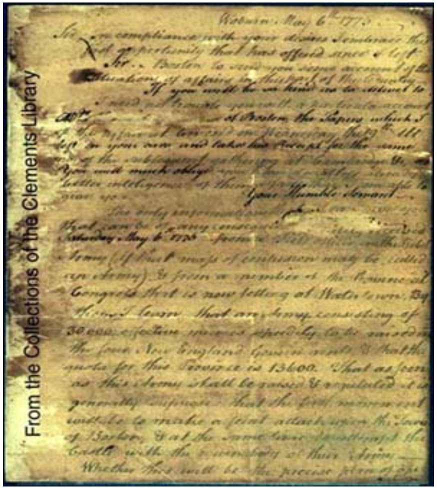
Invisible ink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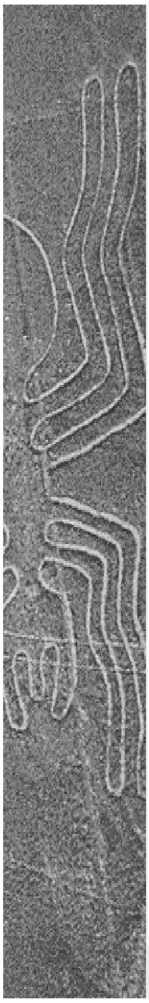
Tatoo

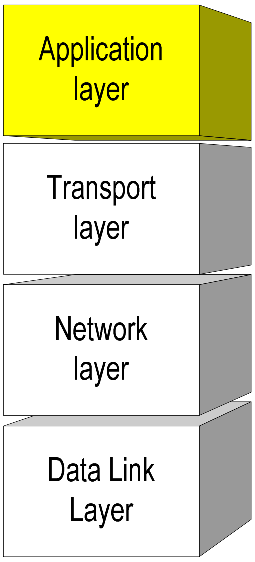
↑ http://www.si.umich.edu/spies/methods-ink.html
↖ http://www.si.umich.edu/spies/methods-mask.html
← http://www.miki.hg.pl/tatoo%20maly/Image72.jpg

Steganography was dedicated to hide information **from human**

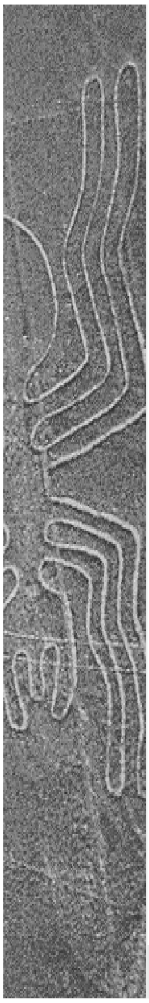


Related Work 1/2

TCP/IP protocol suite

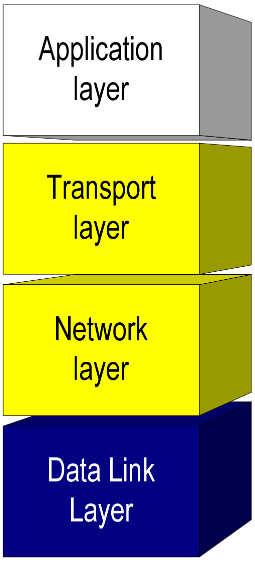


- In the TCP/IP protocol suite multimedia applications are equivalent of old techniques – hidden data is distributed in sound files, images and movies
- Watermarking to protect intellectual property rights
- Network (protocol) steganography – **machine vs. machine problem**
- Field of knowledge established in scientific literature in 1996
- Discovered again after 911 (September 11th, 2001)

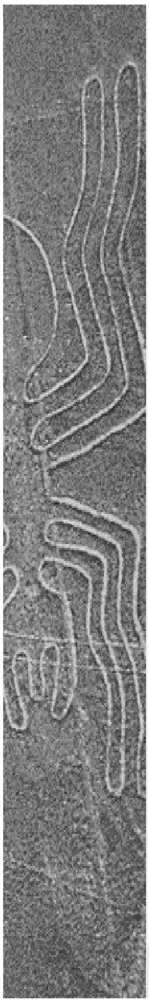


Related Work 2/2

TCP/IP protocol suite

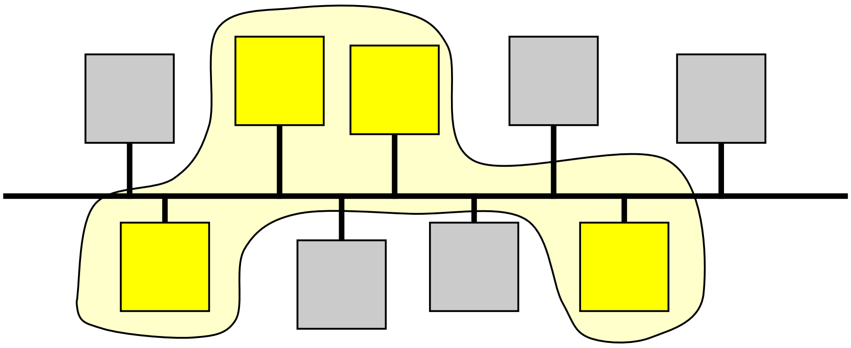


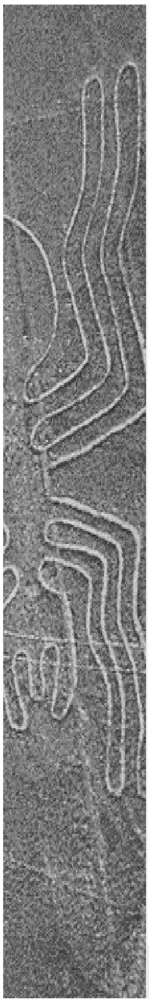
- A focus on transport and network layers hidden communication (because of WAN):
  - Usage of optional fields
  - Semantic changes
  - Improper, but acceptable construction of protocol data units (packets)
- In a data link layer
  - As above plus:
  - Usage of unused transmission code space
  - In LAN: modification of the collision detection system in Ethernet (Theodore G. Handel and Maxwell T. Sandford- Weapon Design Technology Group – Los Alamos National Laboratory)



HICCUPS Concept 1/2

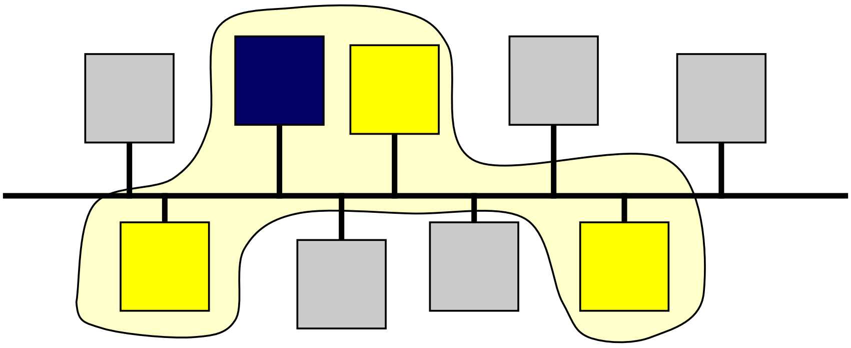
- Shared medium networks use broadcast medium (for example air) - it creates possibility of “hearing” all frames with data transmitted in medium
- Hidden group with common knowledge
- Basic mode for steganographic system – usage of low bandwidth hidden data channels (1% of frame size)

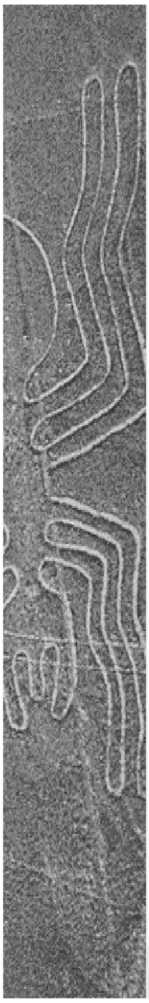




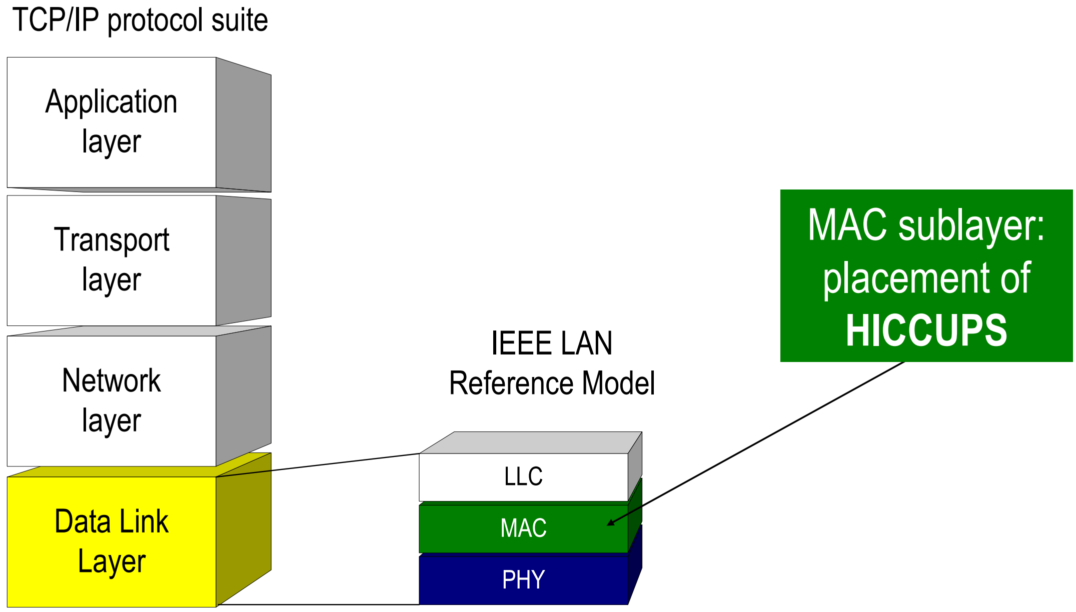
HICCUPS Concept 2/2

- A station sends corrupted (= with bad checksum) frame
- Remaining hidden stations are changing their mode of operation to the „corrupted frame mode” (high bandwidth - almost 100% of frame size) – for observers it looks like **hiccups**
- Additionally: usage of network protected by cryptographic mechanisms to have an exquisite noise



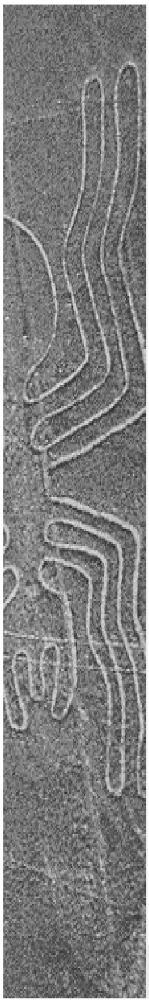


IEEE LAN RM vs. TCP/IP Protocol Suite



Legend:
LLC - Link Layer Control
MAC - Medium Access Control
PHY - Physical Signalling

Shared medium networks



Properties of Network Environment for HICCUPS

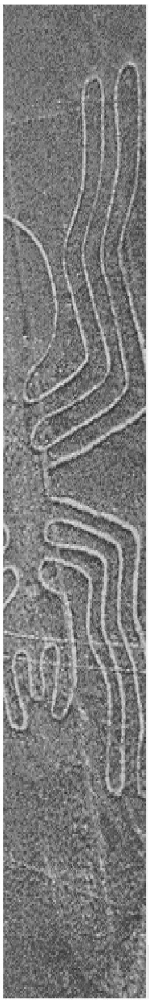
P1: shared medium network with possibility of frame’s interception:
- CSMA (Carrier Sense Multiple Access)- **Aloha**
- CSMA/CD (CSMA with Collision Detection)- **Ethernet**
- CSMA/CA (CSMA with Collision Avoidance) – **WLAN IEEE 802.11**
- **Token Bus**

P2: publicly known method of cipher initiation for instance by initialization vectors

P3: integrity mechanisms for encrypted frames for instance one-way hash function, Cyclic Redundancy Code – CRC

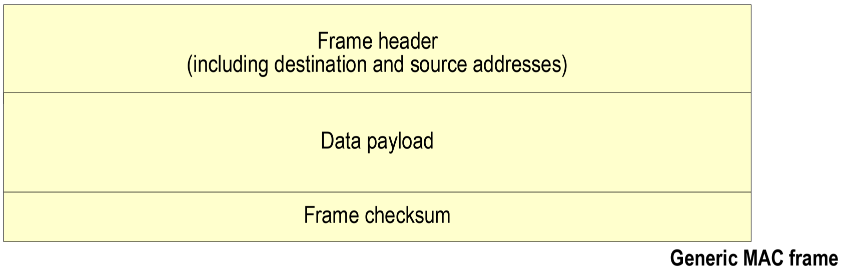
(CRC is rarely strong enough for protecting integrity, but it is used in WLAN IEEE 802.11 for such purpose)

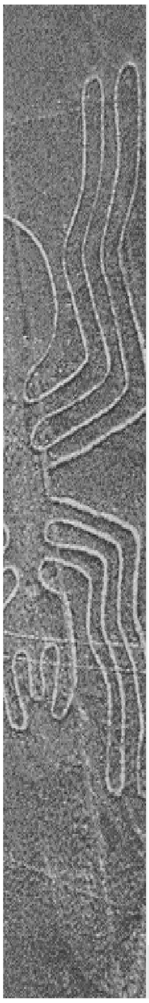
P1 – essential, **P2** and **P3** - optional



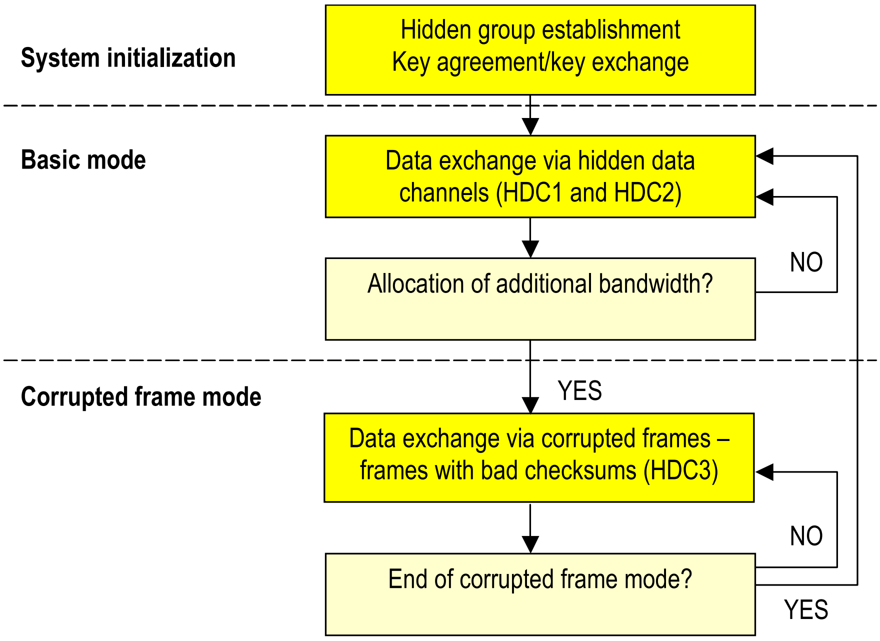
Hidden Data Channels

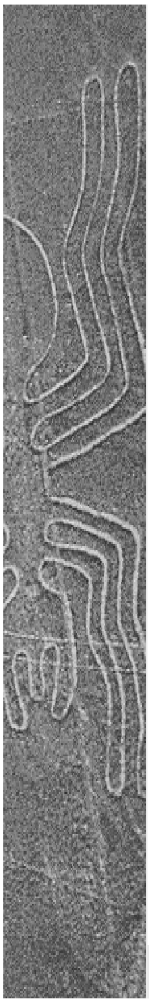
- **HDC1:** channel based on cipher’s initialization vectors
- **HDC2:** channel based on MAC network addresses (for example destination and source)
- **HDC3:** channel based on integrity mechanism values (for example frame checksums)
- For network with **P1 only**: **HDC2** and **HDC3** are used





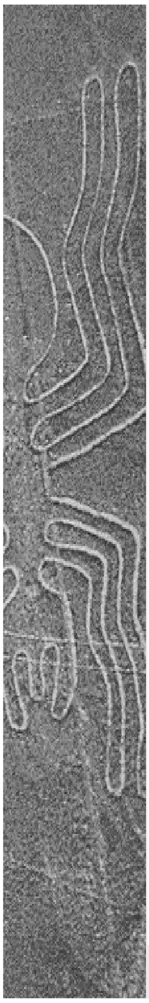
General HICCUPS Operation Scheme


System initialization
Hidden group establishment
Key agreement/key exchange
Basic mode
Data exchange via hidden data channels (HDC1 and HDC2)
Allocation of additional bandwidth?
NO
YES
Corrupted frame mode
Data exchange via corrupted frames – frames with bad checksums (HDC3)
End of corrupted frame mode?
NO
YES



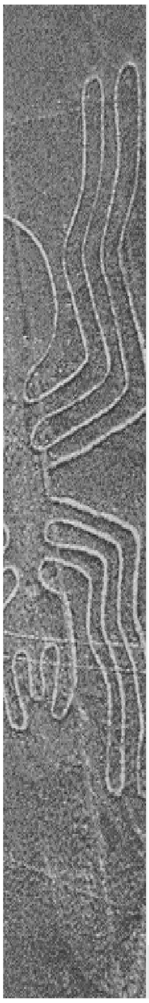
Functional Parts of HICCUPS

- **FP1**: network cards dedicated, for example, to IEEE 802.11b/g; network cards should have possibility to control HDC1-HDC3 and data payload in MAC frame
  - After investigations in network card market we found no interface that allows to produce frame with given CRC
  - Our work is focused on developing self-made network card or reprogramming existing software in available network cards
  - The patent application P.359660 includes a proposal of the generic network card for HICCUPS
- **FP2**: management system to control HDC1-HDC3 and data payload in MAC frame



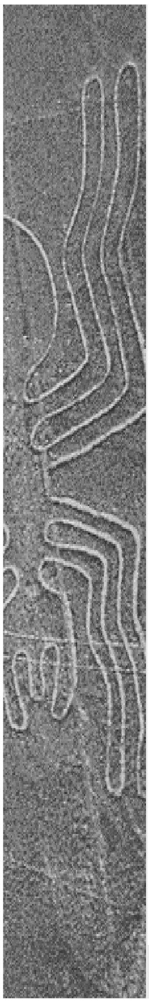
The Management System

- The management system (FP2) may be produced as software or hardware and should perform such functions:
  - joining hidden group
  - leaving hidden group
  - providing interface to upper network layer to control HDC1-HDC3 and data payload in MAC frame
- with cryptographic extension:
  - key agreement/key exchange
  - key refresh
  - encryption/decryption



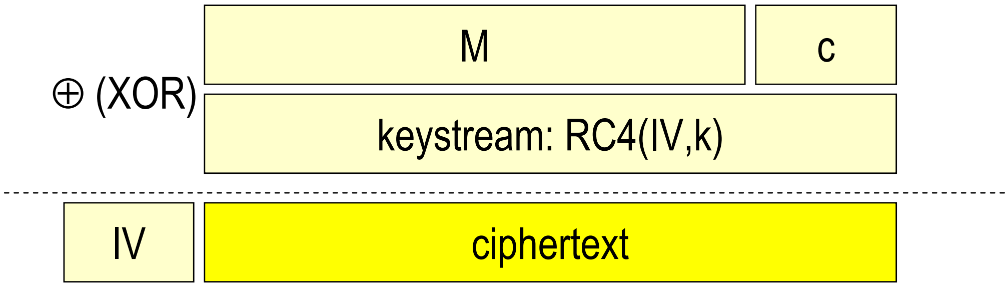
Properties of WLAN Network Environment

- Mean bit error rate can range from 10^{-3} to 10^{-7}. Typical frame error rate (FER) for WLAN and TCP/IP protocol suite is 2-3% but mobility of station increases FER by about 30%
- **P1.WLAN:** wireless local area network with bus topology and medium access mechanism CSMA/CA
- **P2.WLAN:** publicly known method of RC4 cipher initiation by initialization vectors
- **P3.WLAN:** integrity mechanisms for encrypted frames – CRC-32



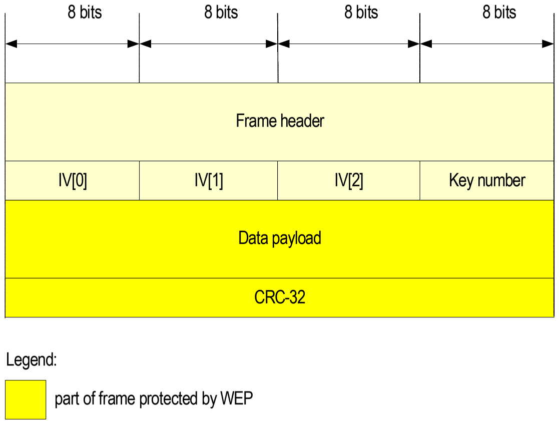
IEEE 802.11 Wired Equivalent Privacy

- **64-bit RC4** (effective 40-bit)
- **128-bit RC4** (effective 104-bit) – vendor standard
- A sender and a receiver share secret key – **k**
- initialization vector – **IV**
- message – **M**
- **RC4(IV,k)** generates keystream
- checksum **c** performed by **CRC-32**
- manual key distribution



Hidden Data Channels in WLAN

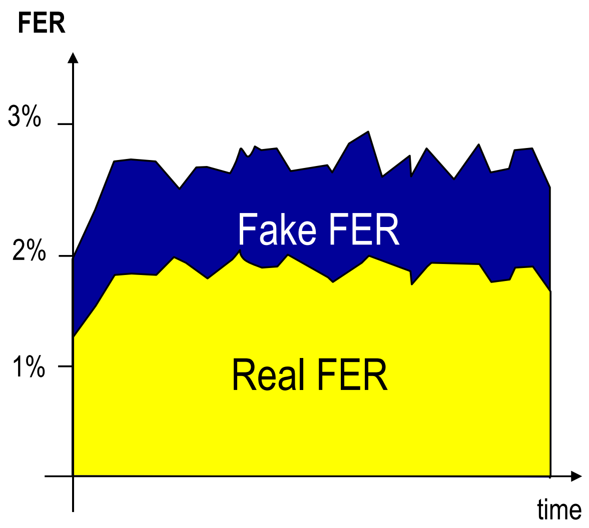
- **HDC1.WLAN:** channel based on RC4 initialization vectors: 24 bit
- **HDC2.WLAN:** channel based on MAC network addresses:
  - Destination Address: 48-bit
  - Source Address: 48-bit
  - Receiver Address: 48-bit
  - Transmitter Address: 48-bit
- **HDC3.WLAN:** channel based on integrity mechanism values – armed with WEP: 32- bit

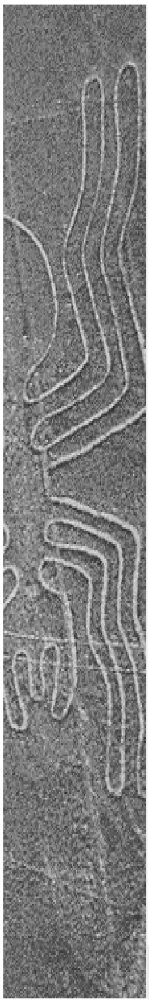


IEEE 802.11 MAC frame armed with WEP

„Right to Talk" System for WLAN

- All stations involved in hidden communications will be keeping frame error rate (FER) worse than it really exists
- In reality there is no way to predict FER at specific point of wireless network environment – only physical existence of station or sensor gives opportunity to measure frame error rate
- Keeping FER bad enough consists of generating corrupted packets with data useless for steganographic system





Conclusions

- HICCUPS is a new network steganographic system dedicated to shared medium networks especially to WLAN
- Main novelty of the system is usage of frames with bad checksums as a method of creating additional on-demand bandwidth for steganographic purposes
- Elastic on-demand bandwidth: kilobits-per-second (not several bits-per-second)
- System can be applied to many of the existing wireless public networks (including sensor networks)

Thank you for your interest!

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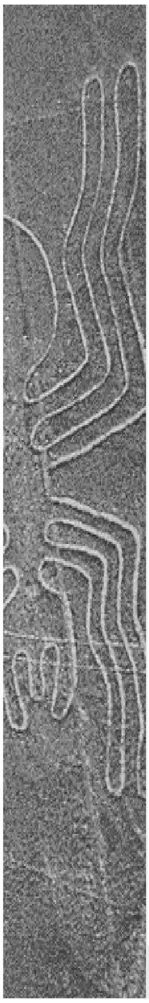

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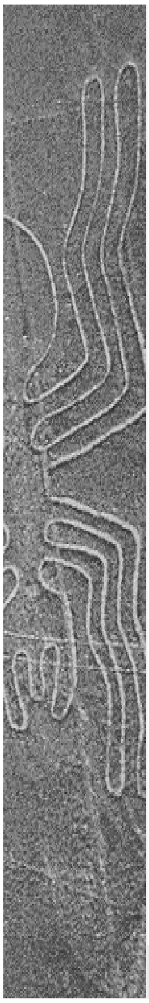

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