Wanna TEMPEST your computer?

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TLS-SEC

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TLS-SEC

Toulouse
Hacking
Convention

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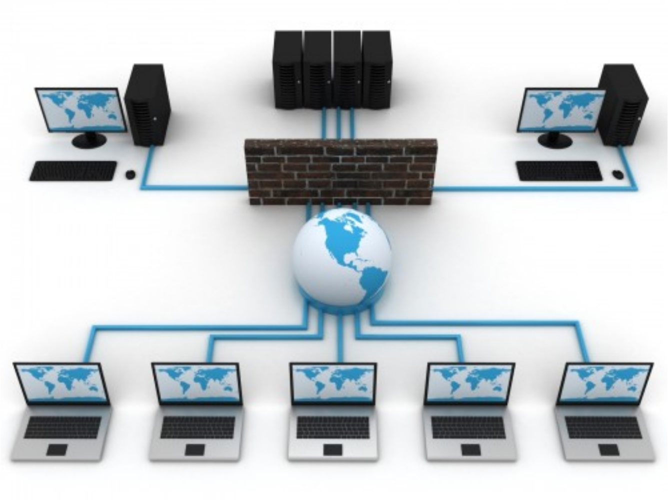
"Projet long" context

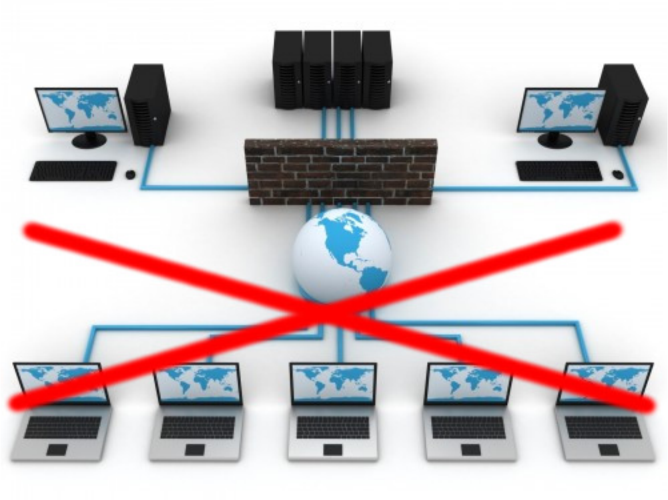
THC 2018 Challenge

- Prepare tutorial challenge
- Work based on *GSMem: Data Exfiltration from Air-Gapped Computers over GSM Frequencies* (24th USENIX Security Symposium)
- "Challenge" : data exfiltration form an air-gapped computer
- "Tutorial" : guide the challenger step-by-step
- Main idea : follow how we succeed to reproduce a part of the paper

Air-gapped networks



Air-gapped networks



Electromagnetic emanations

Emanations

- Each electronic device has emanations
- Could be optical, electronical, acoustical, mecanical or electromagnetical
- Focus on electromagnetic emanations

TEMPEST

- Name given by NSA for standards protecting against electromagnetic emanations
- Context : EMSEC, surbpart of COMSEC

Challenge context

Goal

Get a password stored on the air-gapped computer

Problem

Air-gapped computer $\Longrightarrow$ no possibility to gain access and/or exfiltrate data via network

Solution

Use electromagnetic emanations to create a covert channel and exfiltrate data

Technical environment

Devices

- 1 air-gapped computer (attacked computer)
- 1 standard computer (attacker's computer)

Tools

- Spectrum analyzer
- Software-defined radio : USRP/RTL-SDR
- Antennas
- Softwares : URH/GNURadio

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Transmission without specific component

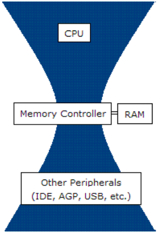
Our target (remind)

Use electromagnetic emanations to create a covert channel and exfiltrate data

Problems

- Computer's electromagnetic emanations → low amplitude
- Amplitude increase ⇒ circuit tension increase

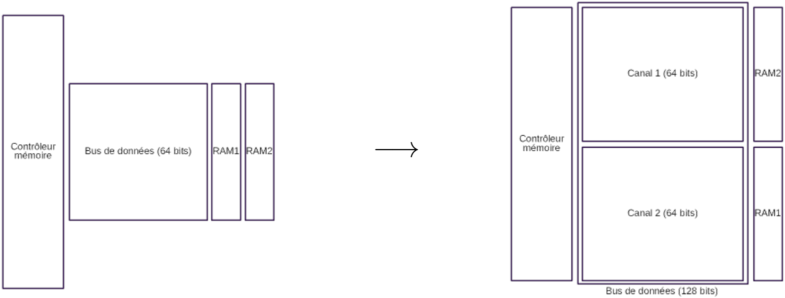
Problem bypass : Multi-channel memory architectures



Memory access

- Memory controller → bottleneck
- Intel/AMD → Multi-channel memory architectures
- Increase data bus size :
  - Double channel ⇒ 128 bits
  - Triple channel ⇒ 192 bits
  - Quadruple channel ⇒ 256 bits

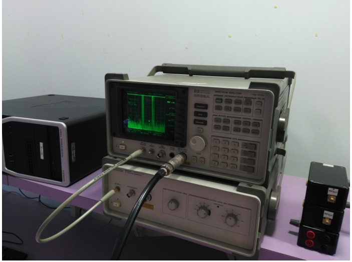
Problem bypass : Multi-channel memory architectures



Consequence using Multi-channel memory

- More electrons in movement at the same time
- Significant electromagnetic emanations created
- ⇒ Emanations could be used to create covert channel

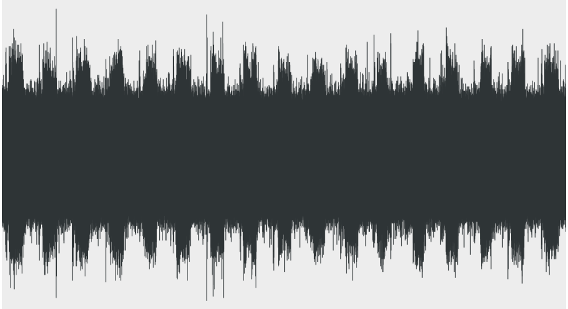
Problem bypass : Multi-channel memory architectures



Application

- Be sure to bypass CPU optimizations
- Use of `MOVNTDQ` instruction on `xmm` registers
- Emanations highlight :
  - Find emission frequency : spectrum analizer
  - Watch signal : USRP/RTL-SDR + URH

Problem bypass : Multi-channel memory architectures



Modulation

- Modulation = information coding process
- Binary Amplitude-Shift Keying (B-ASK) modulation :
  - bit 0 ↔ normal emission level
  - bit 1 ↔ average emission level when multi-channel memory is used

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Demodulation

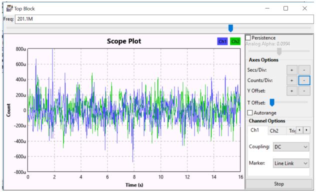
GNUradio

- Free and Open-source Software
- Software Radio
- Signal Processing

Configuration

- Sample Rate
- Frequency
- Period

Raw Signal



Top Block

Freq: 201.1M

Analog Alpha: 0.0994

Coupling: DC

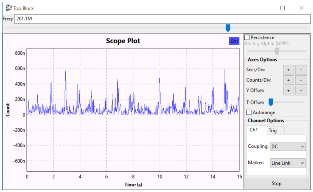
Marker: Line Link

XXXXXXXX

- Complex Signal:
  - In-phase
  - Quadrature
-

$$s(t) = i(t) + jq(t) = r(t).e^j \phi(t)$$

Instantaneous Power



Freq: 201.1M

Analog Alpha: 0.0994

Coupling: DC

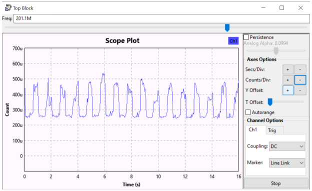
Marker: Line Link

xxxxxx

- Magnitude
-

$$P(t) = |r(t)|^2$$

Sliding Average



Top Block

Freq: 201.1M

□ Persistence

Analog Alpha: 0.0994

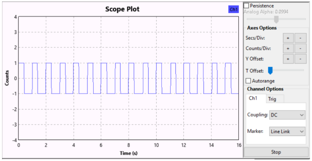
Coupling: DC

Marker: Line Link

xxxxxx

- Number of samples
- Treshold

Square wave



Coupling: DC

Marker: Line Link

xxxxxx

- period
- file sink

Conclusion

Problem

- Noise
- Sample Rate
- Synchronizationtion

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The Malware

Idea

- Same skeleton than the Transmission section
- 1bit/s to reduce error rate

What is transmitted ?

- The message : a file in argument
- End of File : 00001010
- A pattern to localize the message : 11111111
- All of this in an infinite loop

Reception

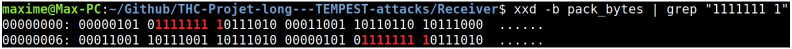
In GNU Radio

- Start the malware before the acquisition to avoid a bug in the first bit transmitted
- Wait around 2 minutes

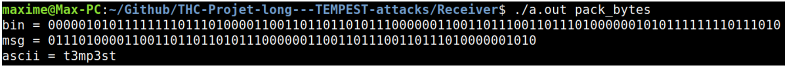
Conversion of the GRC file into our flag

- Localize a first pattern
- Extract bytes from this pattern until the next one
- Convert extracted bytes into ASCII and print it

Reception

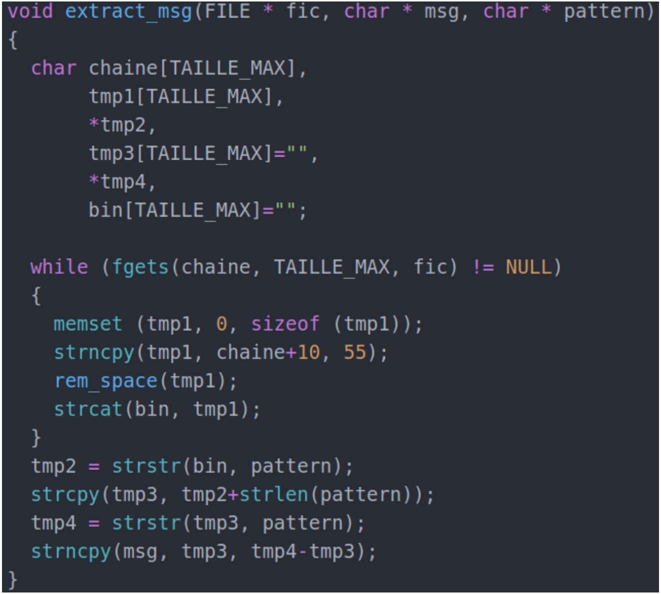


```
maxime@Max-PC:~/Github/THC-Projet-long---TEMPEST-attacks/Receiver$ xxd -b pack_bytes | grep "1111111 1"
00000000: 00000101 01111111 10111010 00011001 10110110 10111000  ......
00000006: 00011001 10111001 10111010 00000101 01111111 10111010  ......
```



```
maxime@Max-PC:~/Github/THC-Projet-long---TEMPEST-attacks/Receiver$ ./a.out pack_bytes
bin = 000001010111111110111010000110011011011010111000000110011011100110111010000001010111111110111010
msg = 0111010000110011011011010111000000110011011100110111010000001010
ascii = t3mp3st
```

Reception



```
void extract_msg(FILE * fic, char * msg, char * pattern)
{
  char chaine[TAILLE_MAX],
       tmp1[TAILLE_MAX],
       *tmp2,
       tmp3[TAILLE_MAX]="",
       *tmp4,
       bin[TAILLE_MAX]="";

  while (fgets(chaine, TAILLE_MAX, fic) != NULL)
  {
    memset (tmp1, 0, sizeof (tmp1));
    strncpy(tmp1, chaine+10, 55);
    rem_space(tmp1);
    strcat(bin, tmp1);
  }
  tmp2 = strstr(bin, pattern);
  strcpy(tmp3, tmp2+strlen(pattern));
  tmp4 = strstr(tmp3, pattern);
  strncpy(msg, tmp3, tmp4-tmp3);
}
```

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Researchers work

- Better equipment
- Signal processing optimization
- Reception until 30m

Limits

- Very limited flow rate to prevent error (error detection ?)
- Can be improve with a frequency modulation (attack USBee)

Countermeasures

- Faraday cage
- Zonal approach
- Antivirus