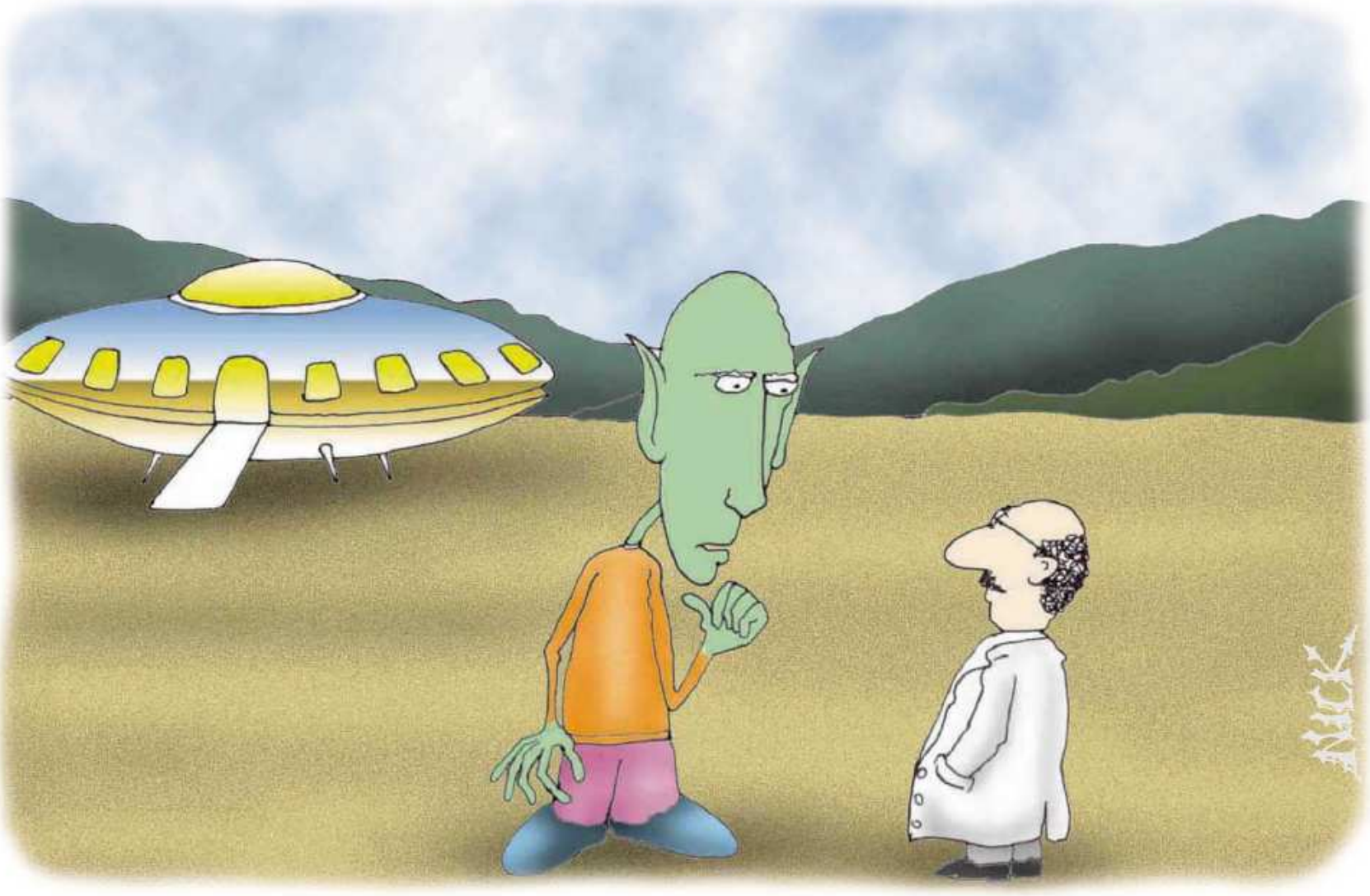
DOTA2024:6
Defense of the Ancients
Sixth topic - Communication methods

Hugh Anderson

National University of Singapore
School of Computing

July, 2024

TLAs...



"That? No, that isn't a U.F.O. It's on the ground now, and you've identified it. That makes it an I.G.O."

Outline

Other networks

Hackable things are everywhere...

The Internet is not the only network of computers.

All around us, things we depend on are built on less well known networks: Water in the taps, power, sewage, gas, oil, automated factories, security systems. They are characterized by:

1. archaic protocols (Allen Bradley...), security by obscurity
2. Developers who claim that “Our engineers/technicians would not tolerate passwords”
3. Languages that should have died years ago (Ladder languages built from relays and switches), and the claim that “Our engineers/technicians would not tolerate HLLs”
4. Radio links, no encryption, dial up and leased phone lines

OtherNets

They are everywhere! Here is a (partial) list:

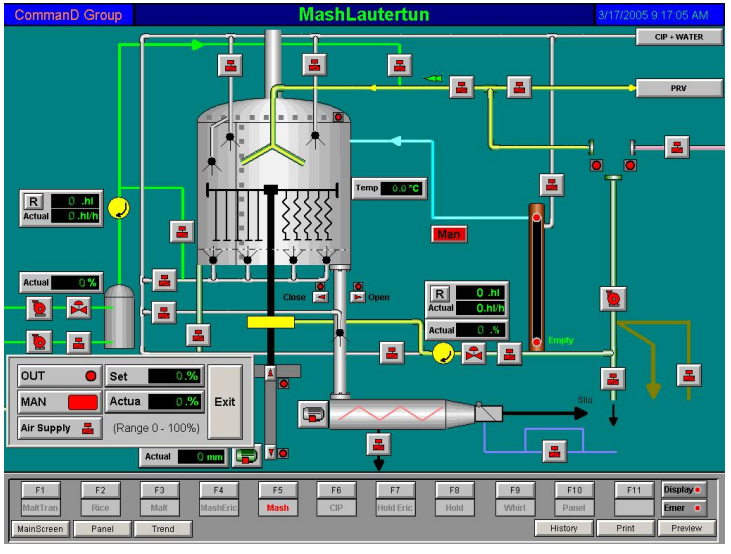
- Phone (Symbian, Android, iOS - all hacked)
- The old wired phone network (exchanges are computers these days)
- Embedded systems, PLC networks (in your plane, your car, your factory)
- The wireless phone network (wireless links, base stations)
- Anarchic/private control networks/systems
  - public utilities - dam control, power reticulation, sewage (dial-up, radio links, SCADA, Allen Bradley...)...
  - commercial - petrol pumps, cash registers, shop stocklist systems (dial-up, leased lines or backboned over Internet)
- Home networks (security, environment control ...)

Othernet hacking scenario #1

Welcome to the wonderful world of SCADA/PLCs...

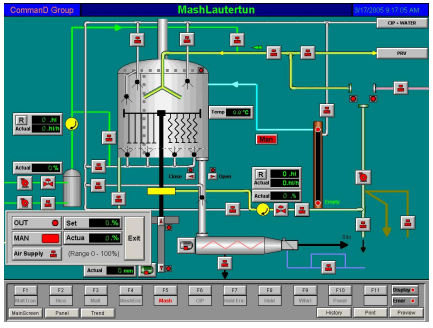
SCADA (supervisory control and data acquisition) is everywhere. Kind of McDonalds but for industrial control, automation, remote management. SCADA equipment controls Singapore's water, gas pipelines, sewage, security systems and so on.

Unfortunately security is seldom addressed, and otherwise sensible people still secure their systems with obscurity.



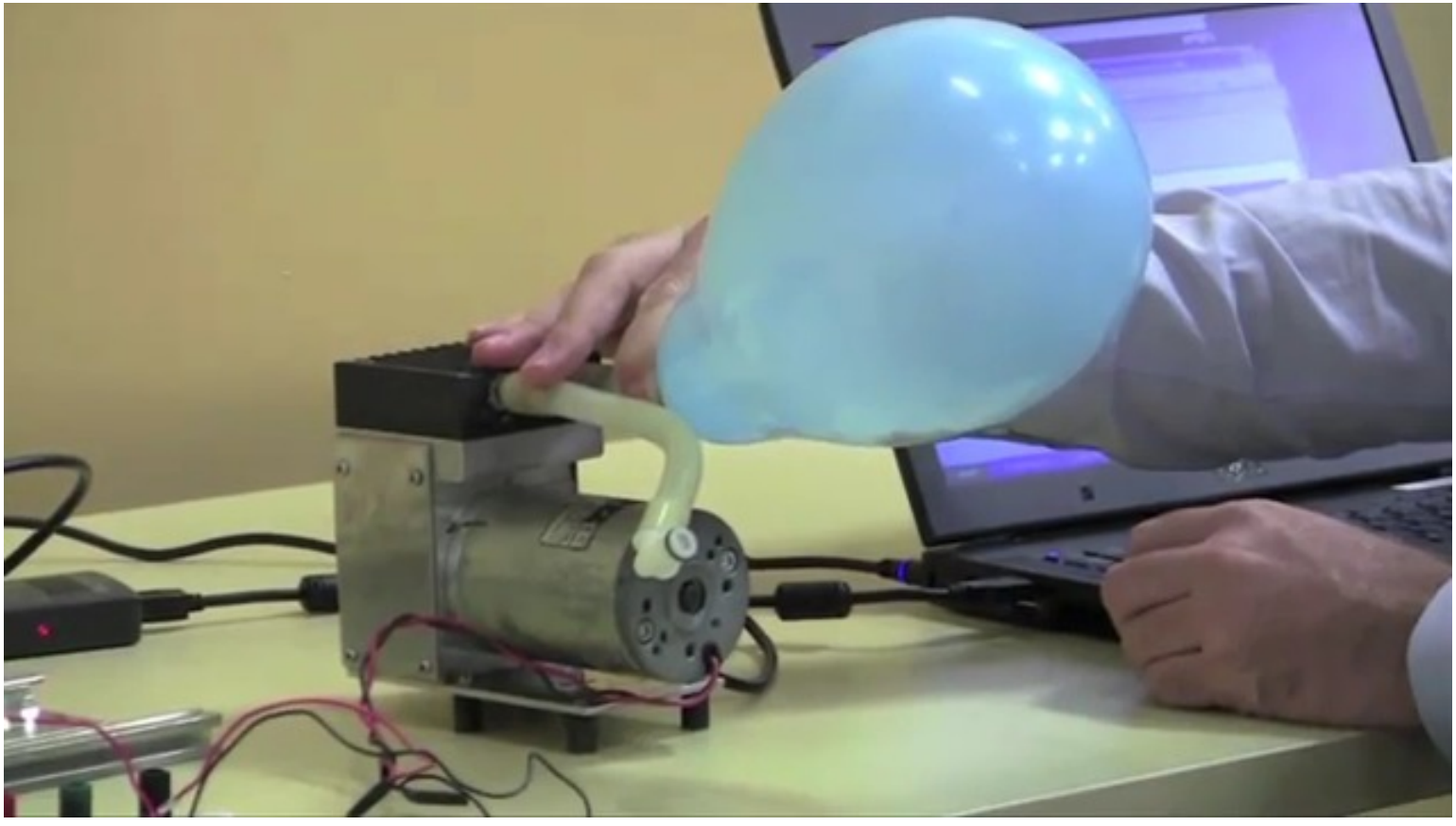
Othernet hacking scenario #1

Welcome to the wonderful world of PLCs. 2 examples:

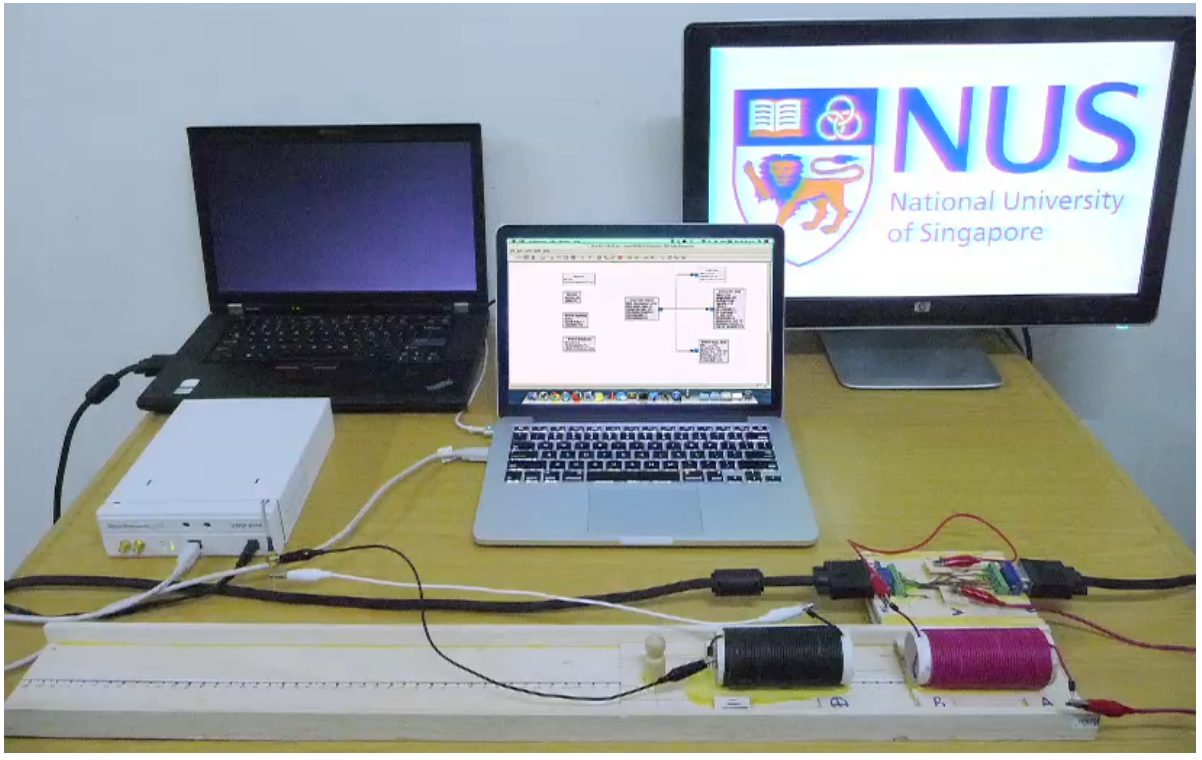


1. An angry man (now jailed) attacked the Maroochy Shire sewage control system (Queensland, Australia), and released a million litres of raw sewage into the environment, using a computer and a special radio.
2. A sophisticated program may have damaged a fifth of Iran's nuclear centrifuges. Stuxnet specifically targeted SCADA and Siemens PLCs, and was probably targetted at Iran.

Balloons should be afraid; very very afraid



Topic: Insecurity



Tempest - Resurrecting images from cable radiation

Paper at:
`https://hugh.comp.nus.edu.sg/DOTA/Files/JinZhouFYP.pdf`

Othernet hacking scenario #1

Spooky CIA stuff...

The CIA claim that there have been multiple instances of successful blackmail of power utility companies around the world. (Note that this may be part of a general strategy of convincing people the world is “dangerous”, so perhaps we should take it with a grain of salt).
The idea is that the blackmailer threatens to turn off the power grid, and (according to the CIA) have turned off power to cities to demonstrate.

Two documented instances of similar activities:

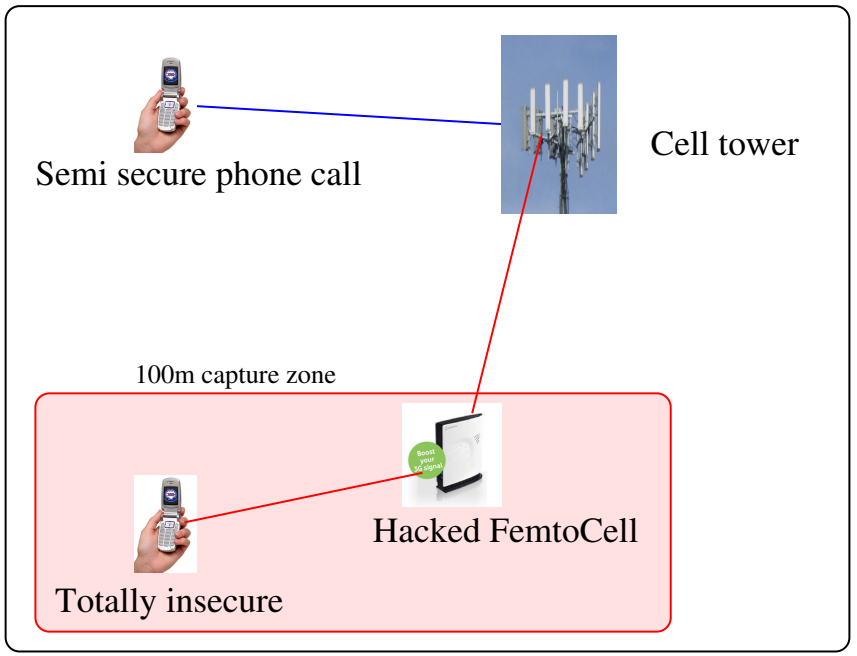
1. Russia’s gas utility control system being taken over for a short period, and also
2. Disgruntled employees in the US hacked traffic light systems in LA to cause chaos

Othernet hacking scenario #2

Welcome to the wonderful world of femtocells...

Vodafone's SureSignal is a neat product which makes cell signals stronger in houses and buildings. It is a small cell base station, called a femtocell.

SureSignal was hacked in 2012. A hacked system can forge calls, record calls, and collect detailed data about the phone/SIM so it can be copied.



Othernet hacking scenario #3

If you cant see it, it must be secret...

The tram switch hack:

A Polish teenager hacked the tram system in the city of Lodz and derailed four trams. Many people were injured. He modified a TV remote control to change track points...

TV-begone... Tram-begone?

Othernet hacking scenario #4

Welcome to the wonderful world of RFIDs...

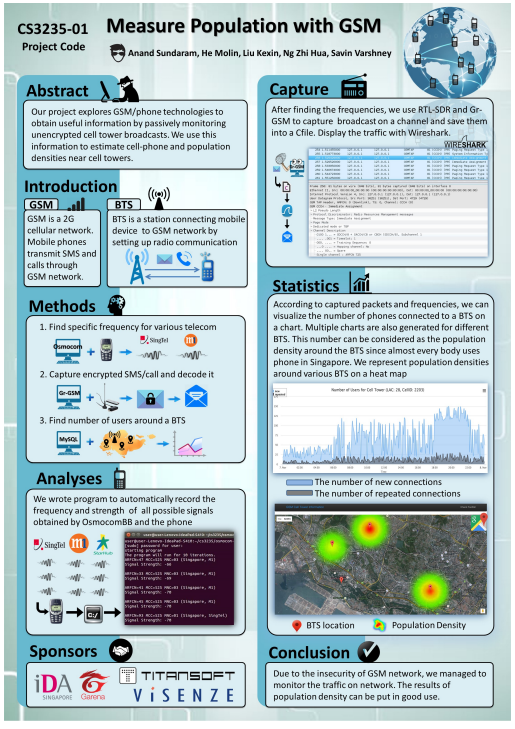
MIFARE Classic, a contactless smartcard widely used in Europe.

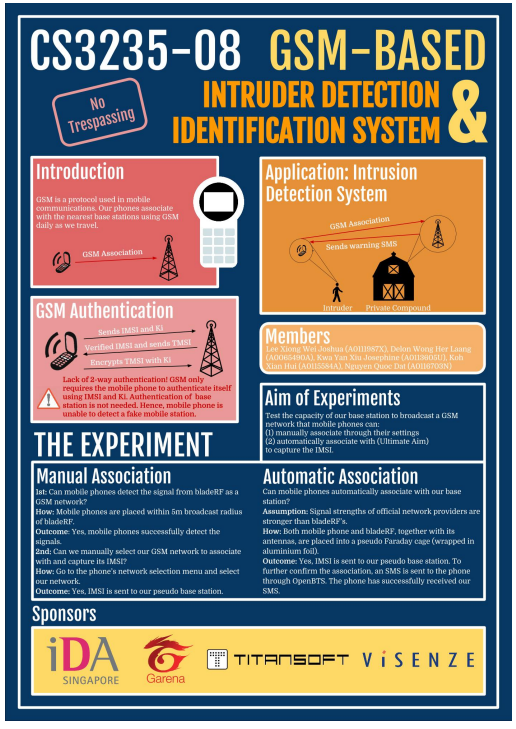
It uses a set of proprietary protocols/algorithms, that were reverse-engineered in 2007. It turns out that the encryption algorithms are already known to be weak (using only 48bits) and breakable `http://en.wikipedia.org/wiki/MIFARE`. All software and hardware details are open, and available for download.

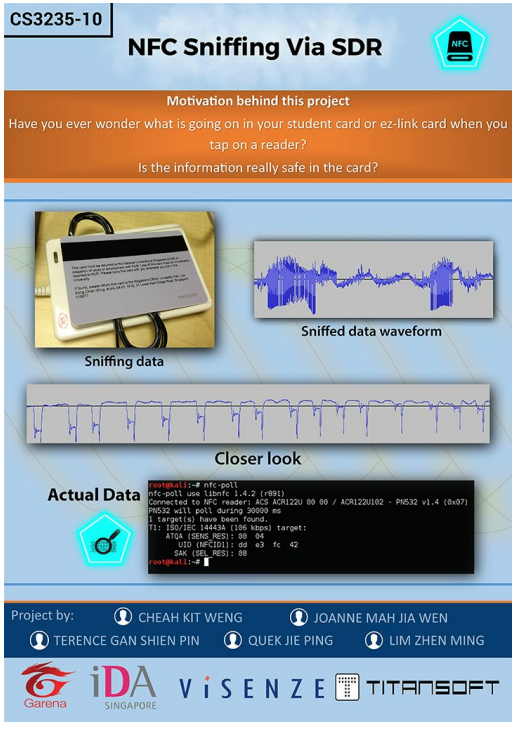
Othernet hacking scenario #4

London underground Oyster card, Malaysia Touch&Go, BMWs etc

Othernet info leaks, projects last sem...







Hardware hacking using $25 and $500 software defined radios, social engineering, inference...

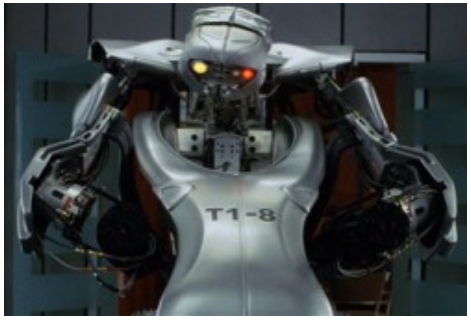
Summary

It sounds bad. Many systems could affect us...

Not only routers, printers, servers, PCs, but also PLCs, control systems. In each of these complex systems, they are only as strong as their weakest link.

Taking the cases of Internets and othernets - There is no adminstrative centre for the Internet, little security (and no administration) on Othernets.

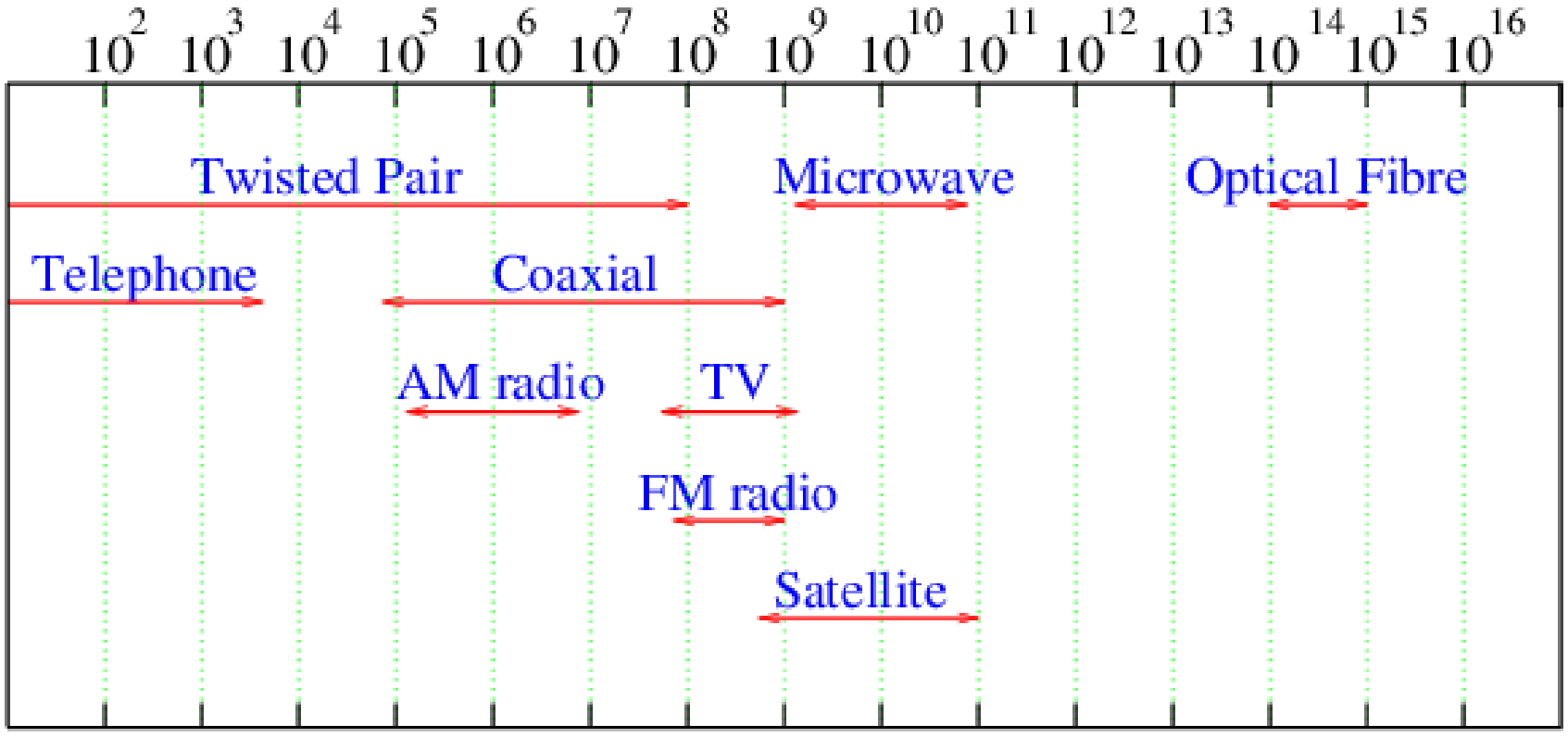
Just organizations trying to make money, cutting corners.



It seems like we cannot trust the machines!

Who knew?

From Hertz, to Terahertz...

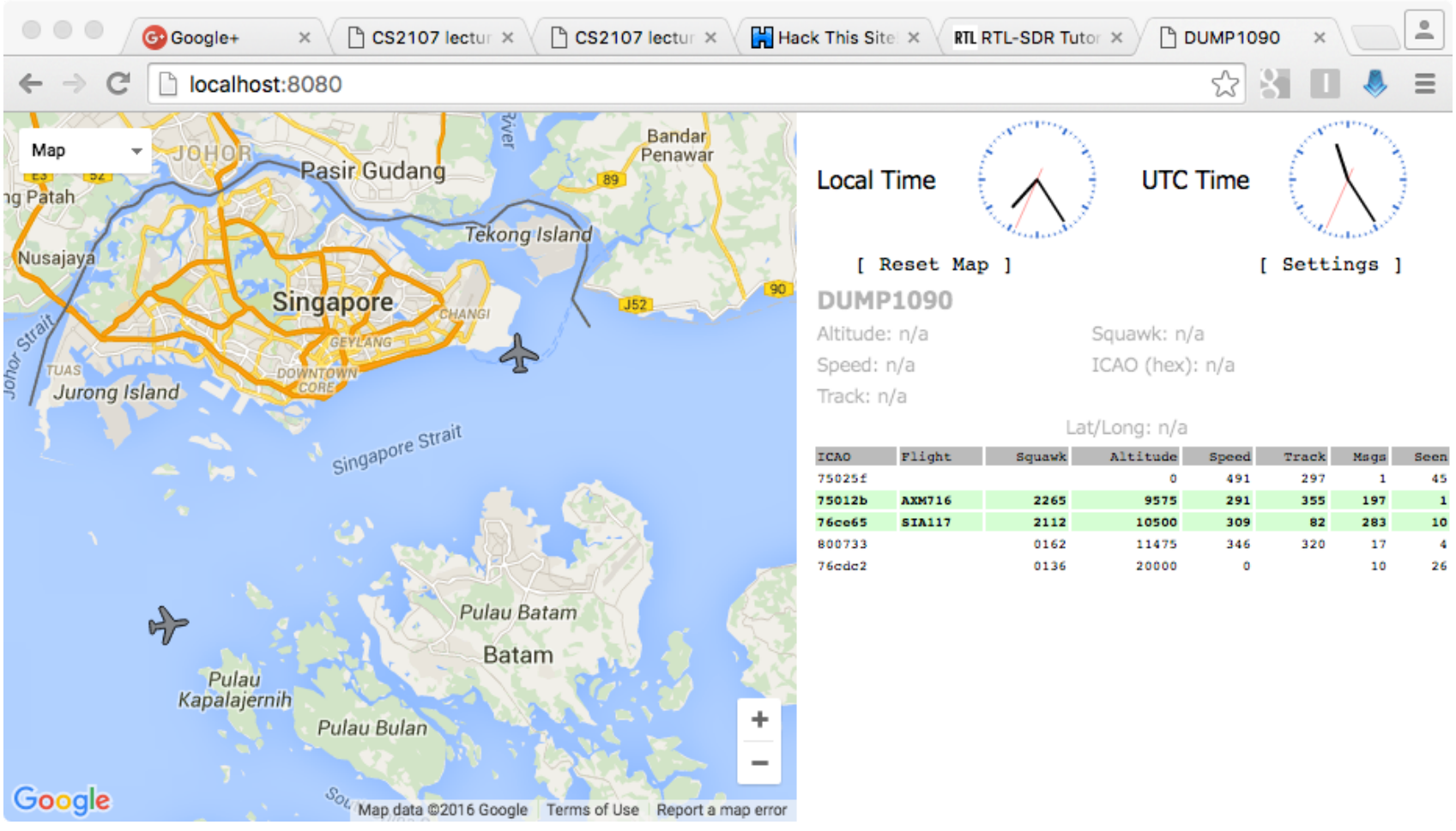


Tools to access the radio spectrum...

or

Hardware hacking using $25 and $500 software defined radios. A range from 1MHz to 5GHz.

Lets see what is at 1090MHz

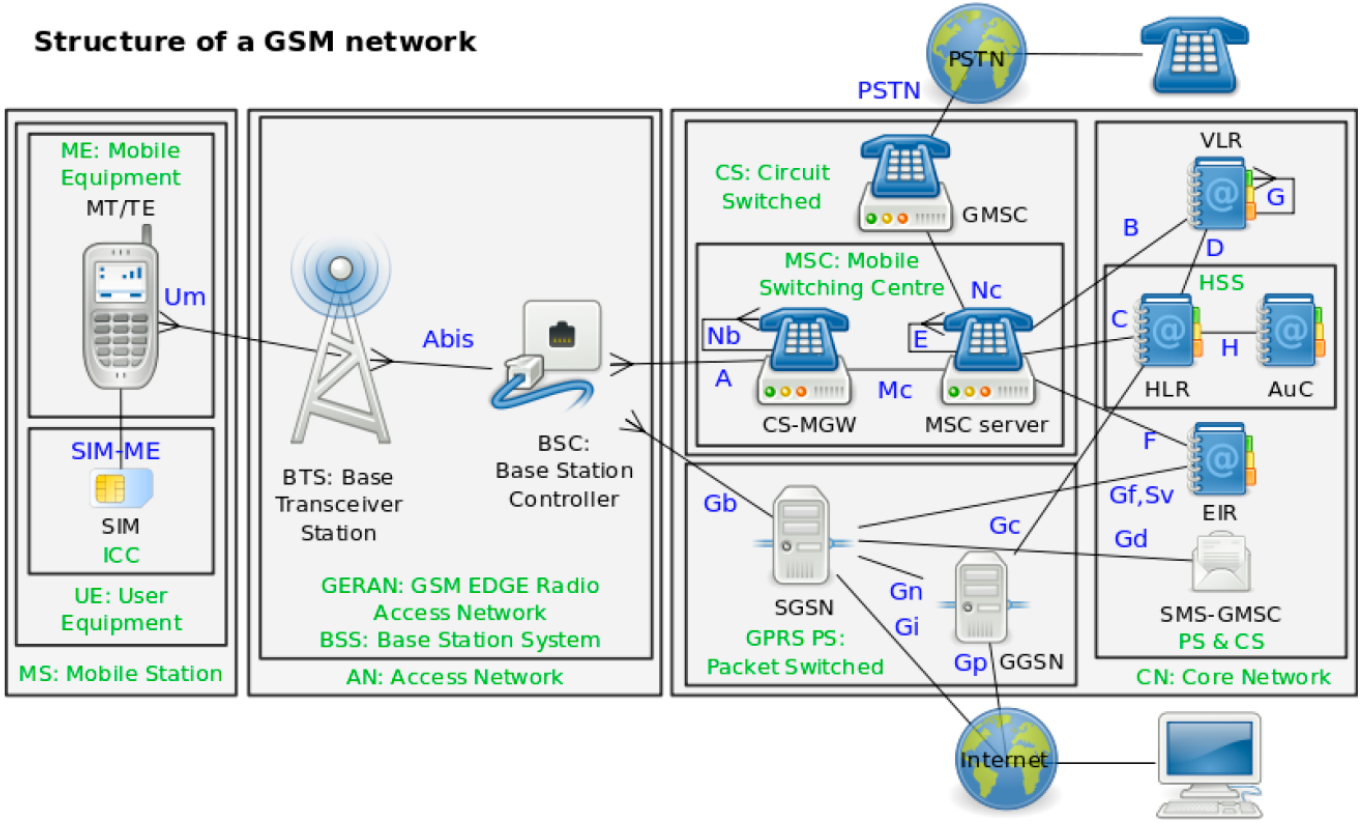


ICAO	Flight	Squawk	Altitude	Speed	Track	Msgs	Seen
75025f			0	491	297	1	45
75012b	AXM716	2265	9575	291	355	197	1
76ce65	SIA117	2112	10500	309	82	283	10
800733		0162	11475	346	320	17	4
76cdc2		0136	20000	0		10	26

Radio signals all around us are supplying us with interesting information.

Phones and GSM

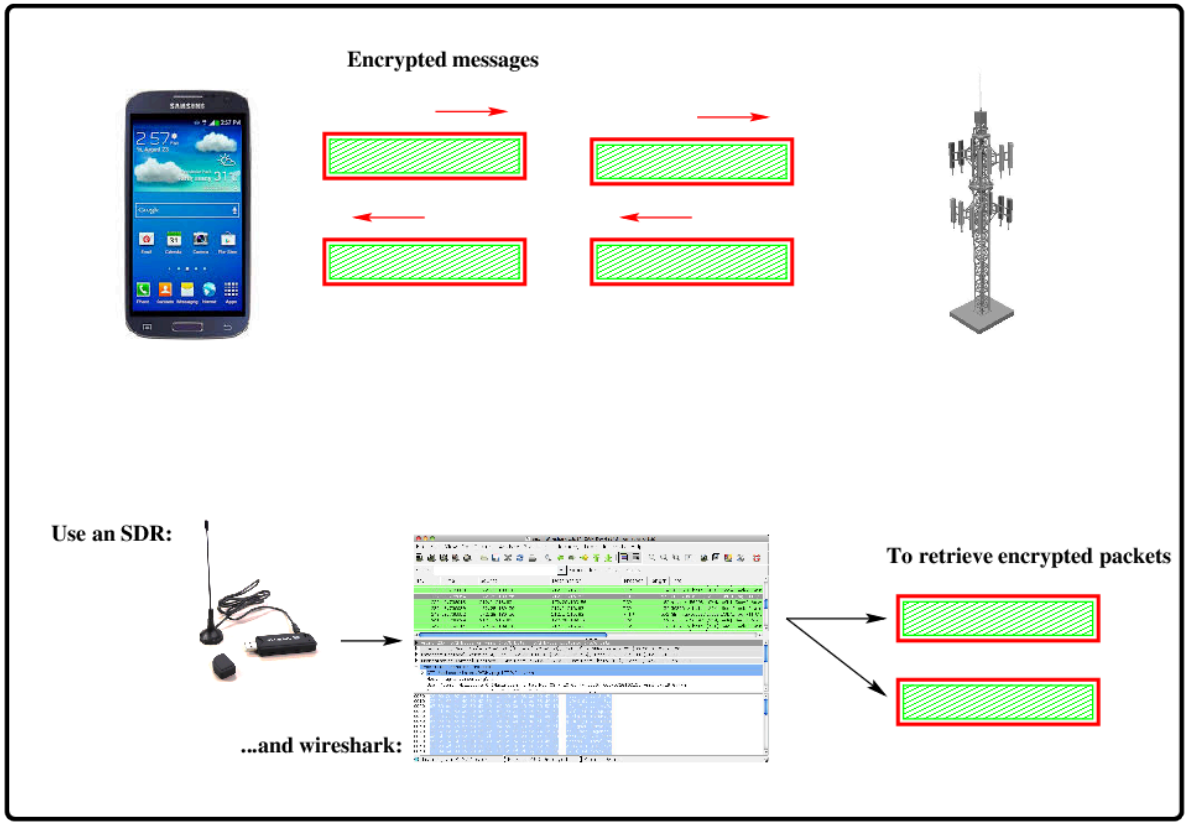
Mobile stations with SIM...



The SIM keeps the private identity of a phone...
Base stations authenticate the SIM/phone.
GSM phone networks on 900/1800 MHz - can we look at them with an SDR?

An attack on phones and GSM

Step 1: get the packets/frames off the air.....



The packets/frames are 124bits, and some are always the same.
In particular, my students found that in Singapore, a “system information type 6” message was found always 306 frames away from another fixed frame.
The decoded frame was all 0x2b!

An attack on phones and GSM

If the plaintext is known...

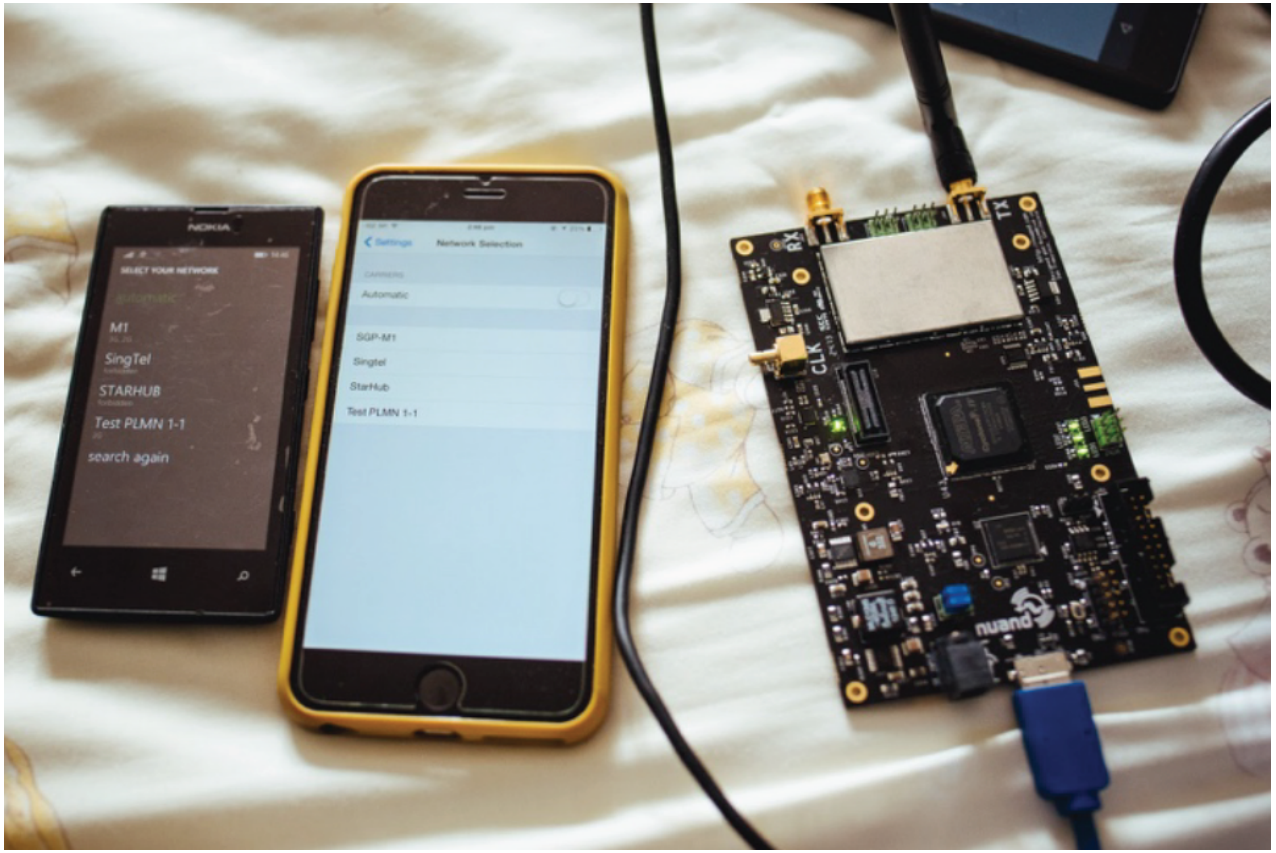
... but the key is not, this is like a hash function. We have seen it before. What can we do?

- Keysize is large (128 bits), but build a rainbow table. The one we have was built in Germany a few years ago, and is 2TB.
- The rainbow table, with good probability, discovers the input to the hash function i.e. the key!

As a result, we have the key used by the phone, and are able to decode this session - the students successfully decrypted SMS messages.
They were not able to do voice, because the simple SDR they were using could only receive a single channel at a time.

GSM man-in-the-middle

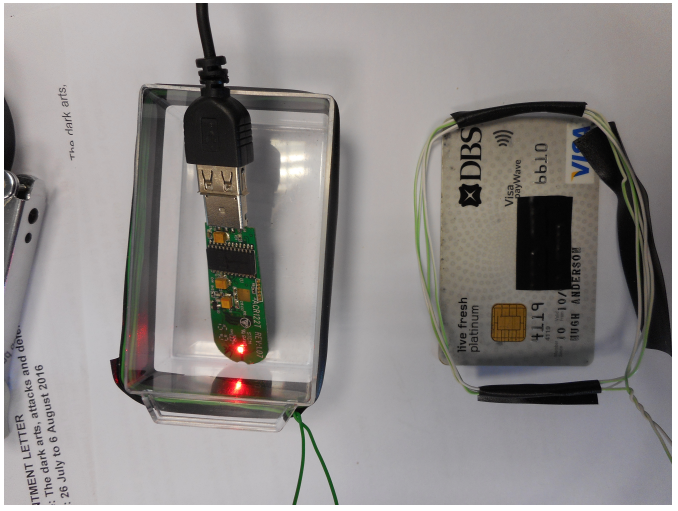
Using software defined radios...



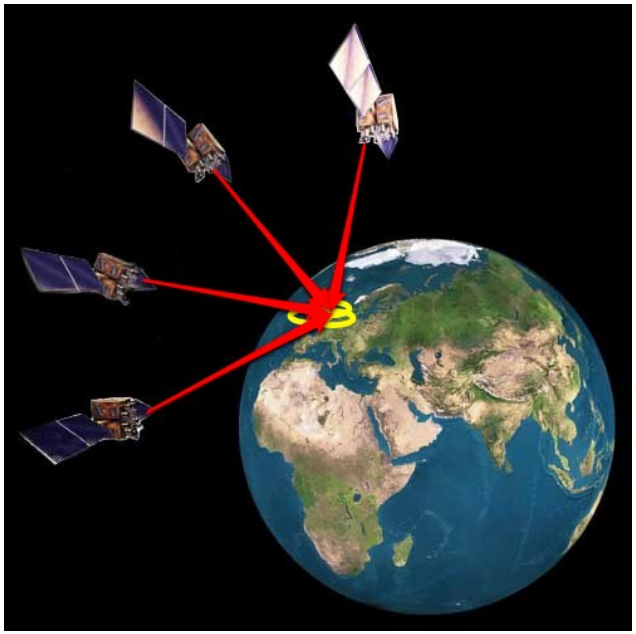
The SDR on the right is pretending to be a base station, the phones on the left can see it... With some care, you can make the phones associate to the SDR instead of Singtel/Starhub, and retrieve interesting information. Students developed a social engineering SMS sequence...

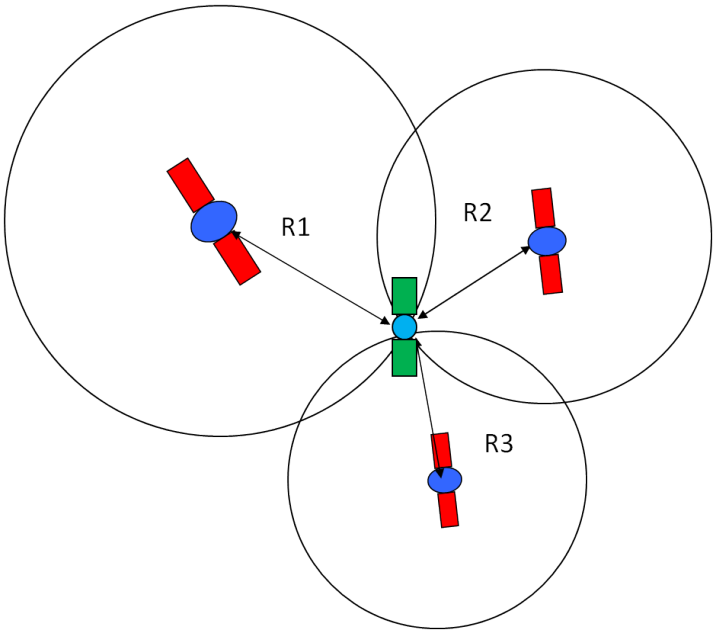
More things to worry about:

A demo with NFC...



Not sure if this fixes the pokemon GO situation...





The satellites are synchronized in time, transmitting on-the-nanosecond signals, which are received in your phone.
The difference in time (signals travel at 300m/uS), can locate the phone to about 15m.

Surface 4 attack, simulate GPS...

A recipe...

Download the gps_sdr_sim from `https://github.com/osqzss/gps-sdr-sim`.

Get the latest ephemeris ffrom
`ftp://cddis.gsfc.nasa.gov/gnss/data/daily/`.
(An ephemeris gives the positions of astronomical objects, in this case the satellites, which are decaying and moving about due to gravity variations).
I got `ftp://cddis.gsfc.nasa.gov/gnss/data/daily/2016/brdc/brdc2160.16n.Z`.

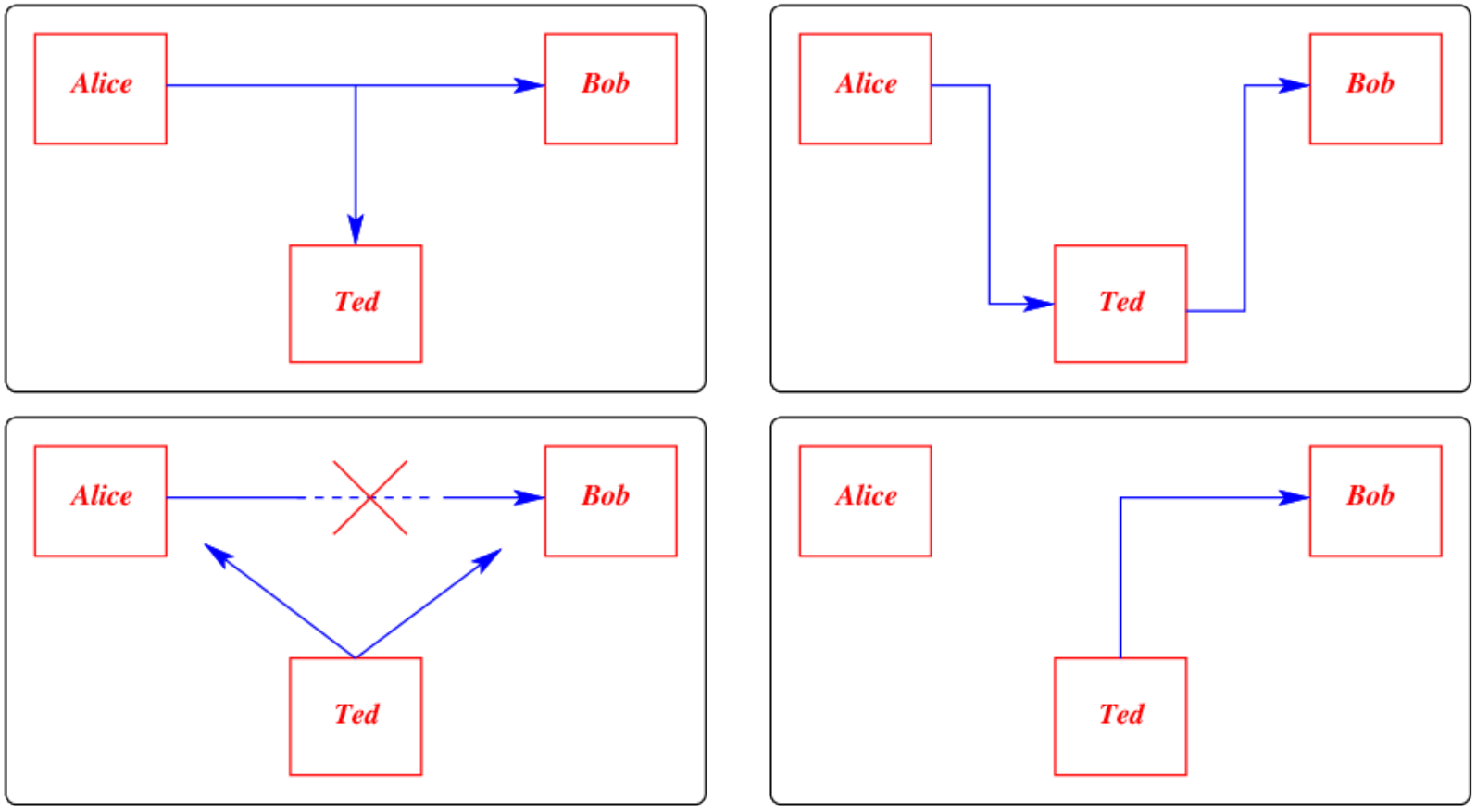
Generate a simulated set of signals from the ephemeris, and a latitude and longitude...

```
./gps-sdr-sim -v -e brdc2160.16n -b 16 -s 2500000 -l -39.332079,175.342537
Hughs-MacBook-Pro:gps-sdr-sim-master hugh$ ls -al gpssim.bin
 -rw-r--r--  1 hugh  staff  2999000000 Aug  4 09:11 gpssim.bin
Hughs-MacBook-Pro:gps-sdr-sim-master hugh$
```

And then attach an SDR, and start sending it...

```
./tx_samples_from_file --args="master_clock_rate=50e6" --file gpssim.bin \
    --type short --rate 2500000 --freq 1575420000 --gain 0 --repeat
```

Attacks and defences anywhere in the spectrum



(... or ... Interception, Modification, Interruption, Fabrication)

Evaluation

It is not magic:

We should evaluate and manage this level of our systems in the same way as we assess and control our computer systems.

Assuming we had a system that made use of communication infrastructure, we should:

- evaluate it's security,
- do a risk assessment,
- ensure we have appropriate controls...

Standards

NIST Special Publication 800-53

For security controls for all U.S. federal information systems. It's approach seems relevant to assessing any security issue, including ones like this.

Within the framework:

- Technical issues include access control, audit and accountability, identification and authentication, and system and communication protection.
- Operational issues include awareness and training, contingency planning, incident response, maintenance and physical protection, and even personnel.
- Management issues include certification, risk assessment and so on.

Summary

It is still not magic:

Defences against communication attacks can encompass a wide range of techniques.

Unfortunately, there is no magic bullet for defending our communication schemes, except perhaps to

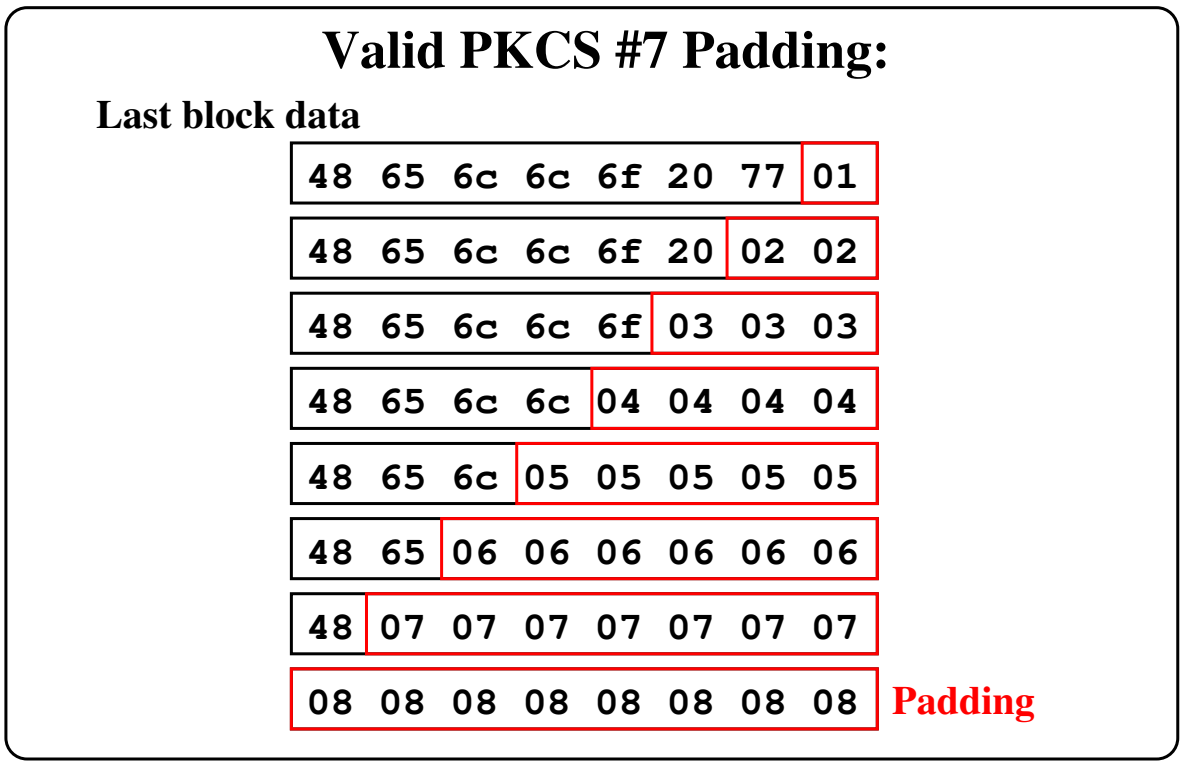
- reach for end-to-end security, where even a corrupted communication network cannot result in malicious activities.

However, even in this scenario, a DoS attack may be possible.

Bit and byte padding for block ciphers...

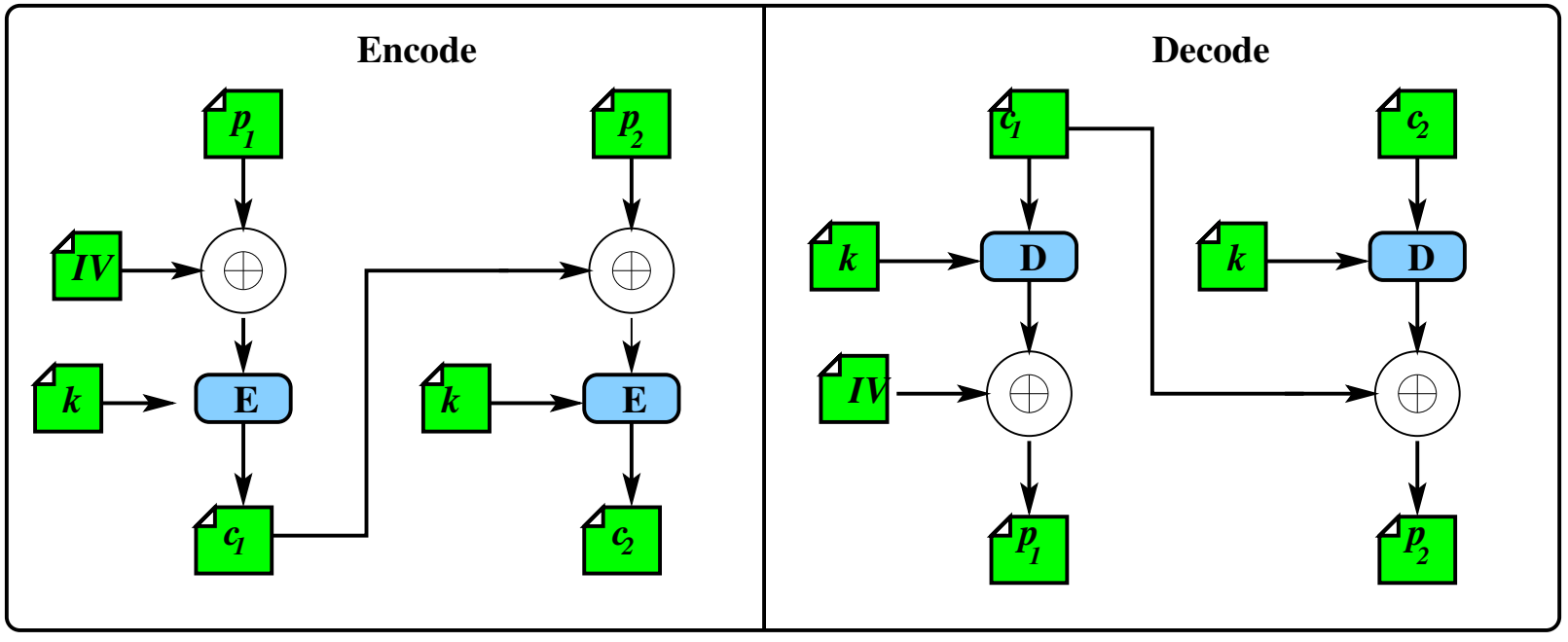
PKCS #7 - a byte-wise padding technique...

One technique is to add a single 1 bit, followed by enough 0 bits to fill out the block.
Another is the PKCS #7 paddings for the final block. Each byte is given as 2 hex digits:



CBC: encoding and decoding...

Encode is XOR, then encrypt...

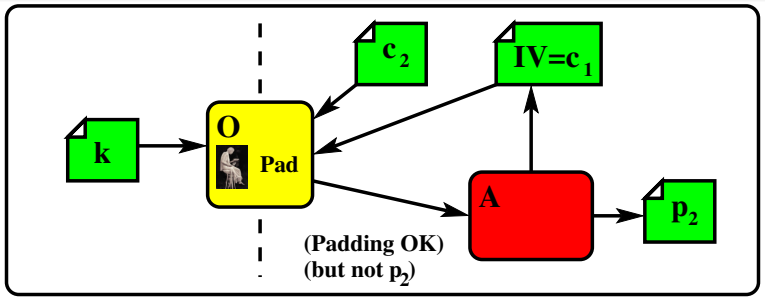


(...and of course, decode is decrypt, then XOR).

Note that when you are decoding, the final plaintext p_2 is the decrypted ciphertext exclusive-ored with c_1.

If there was only one block, the final plaintext p_1 is the decrypted ciphertext exclusive-ored with IV

Padding oracle...



What is a padding oracle?

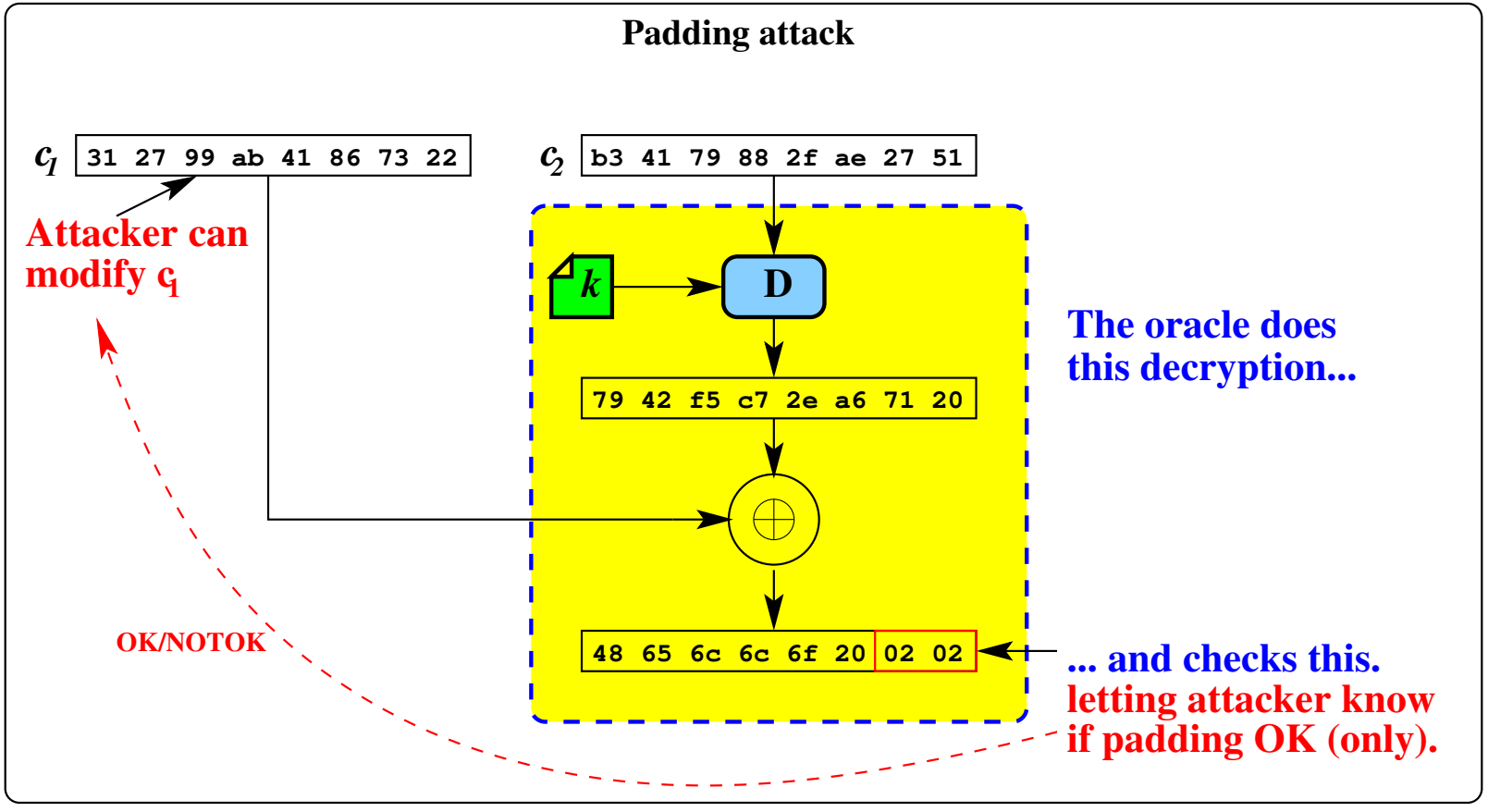
Imagine that you have a bit of software, that, given c_1 and c_2, will tell you if the padding is correct in p_2. If the message was only one block long, given IV and c_1 (as in the lab), it will tell you if the padding is correct in p_1. In general, given c_{n-1} and c_n, it will tell you if the padding is correct.

Is this realistic? Well, yes it is.
When you send a padded, encrypted message to another system, after decrypting, the other system will check the padding, and if it is not valid, will fail immediately. Otherwise it will fail (or succeed) later.
Normal receiving software may leak the correctness of the padding. In the lab, we will give you a program that is a padding oracle.

Note also that an you can directly change each bit/byte of the final plaintext for p_n, because the attacker has control over the input c_{n-1} (or IV as in the lab).

Using the oracle in an attack...

The attacker does not get to see the decrypted data...

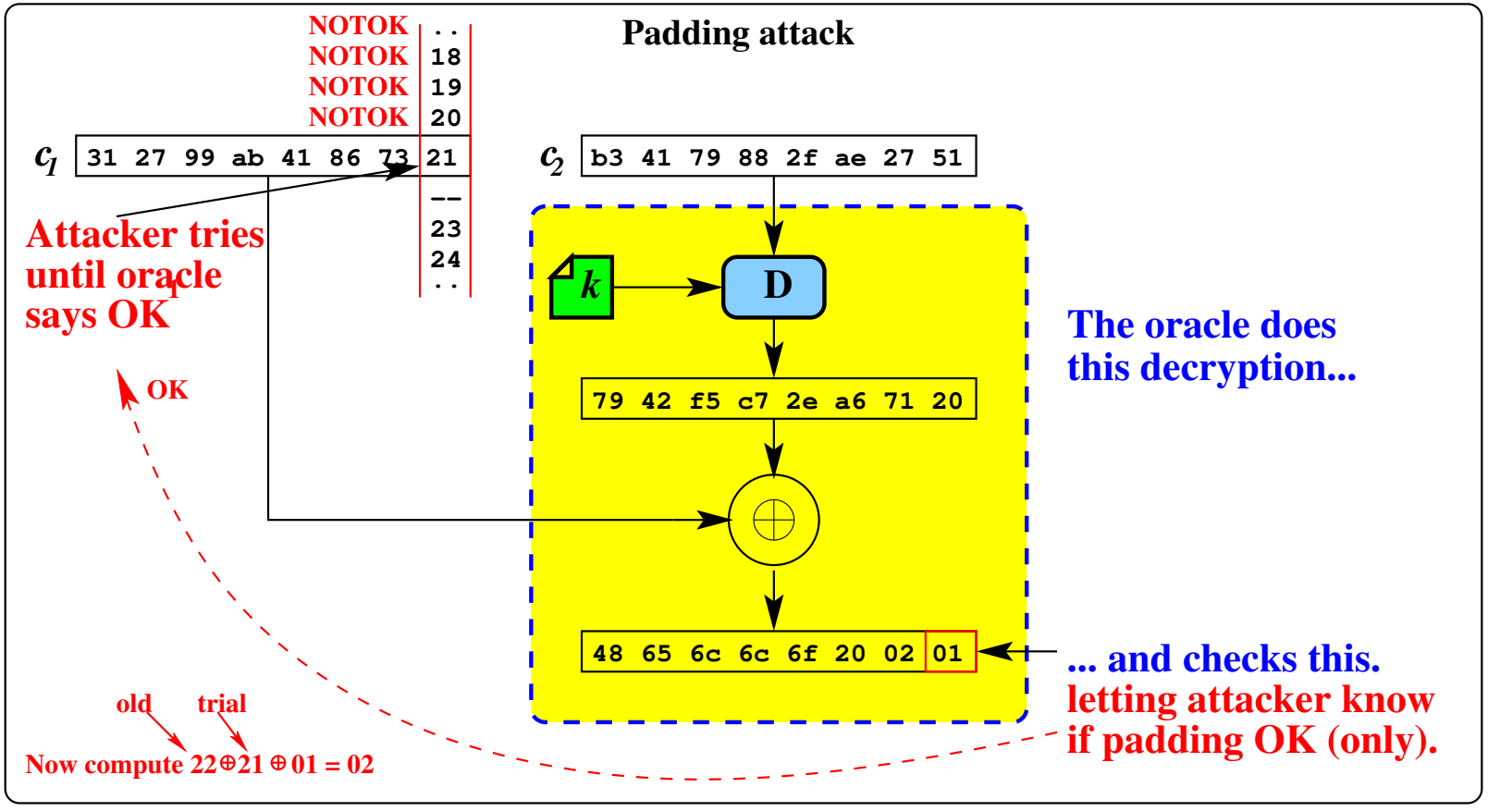


The oracle only learns if the last bytes are correct - they could be `01`, `0202`, `030303`, and so on.

The attacker starts by trying a series of values for the last byte of c_1:

Using the oracle in an attack...

Attacker discovers last byte...

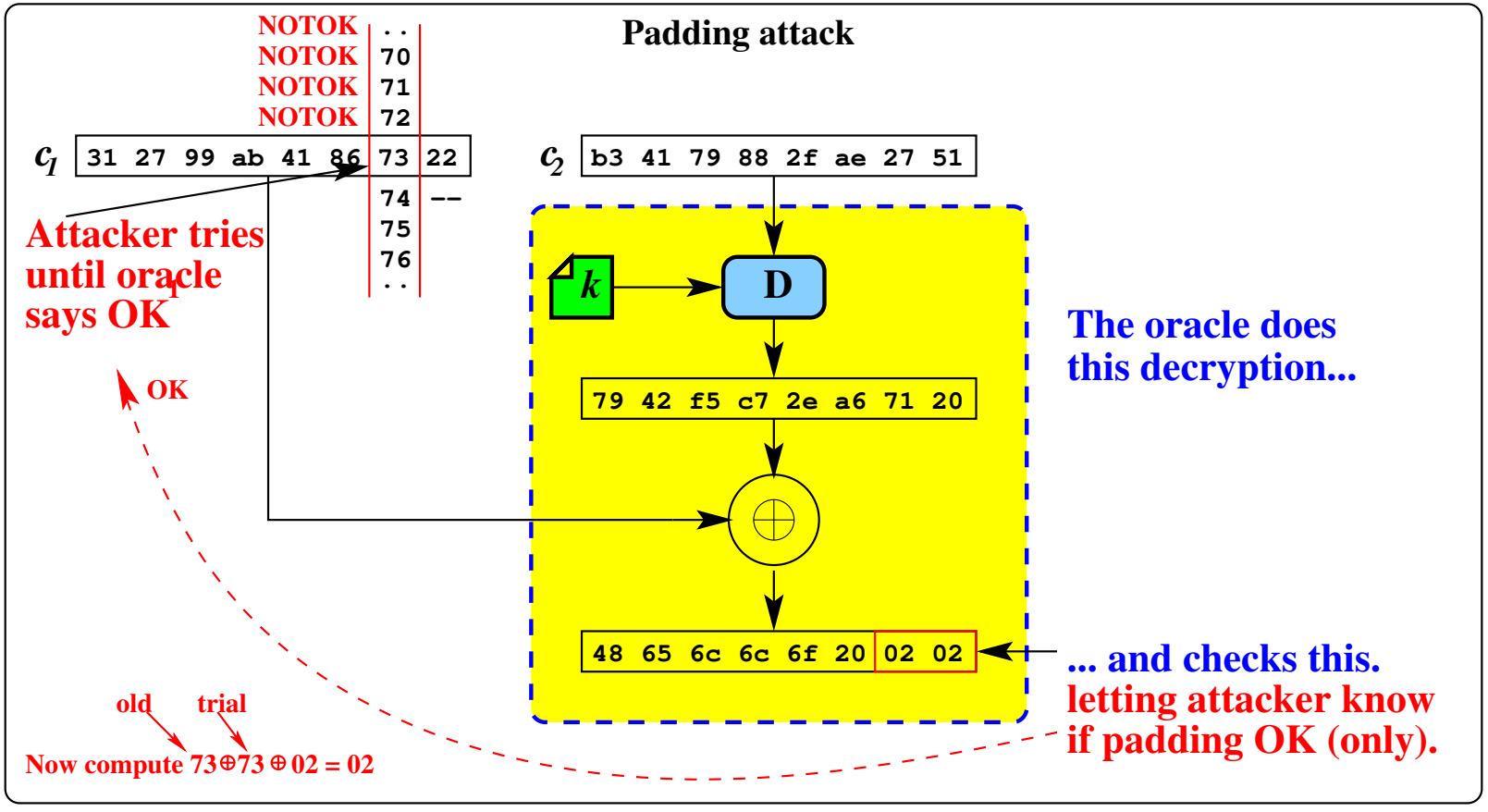


The attacker is trying values in the last byte of c_1 until `01` is the last byte. The oracle will return padding OK...

Attacker now sets the last byte to `02`, and tries for the second-last byte of c_1:

Using the oracle in an attack...

Attacker discovers second-to-last byte...

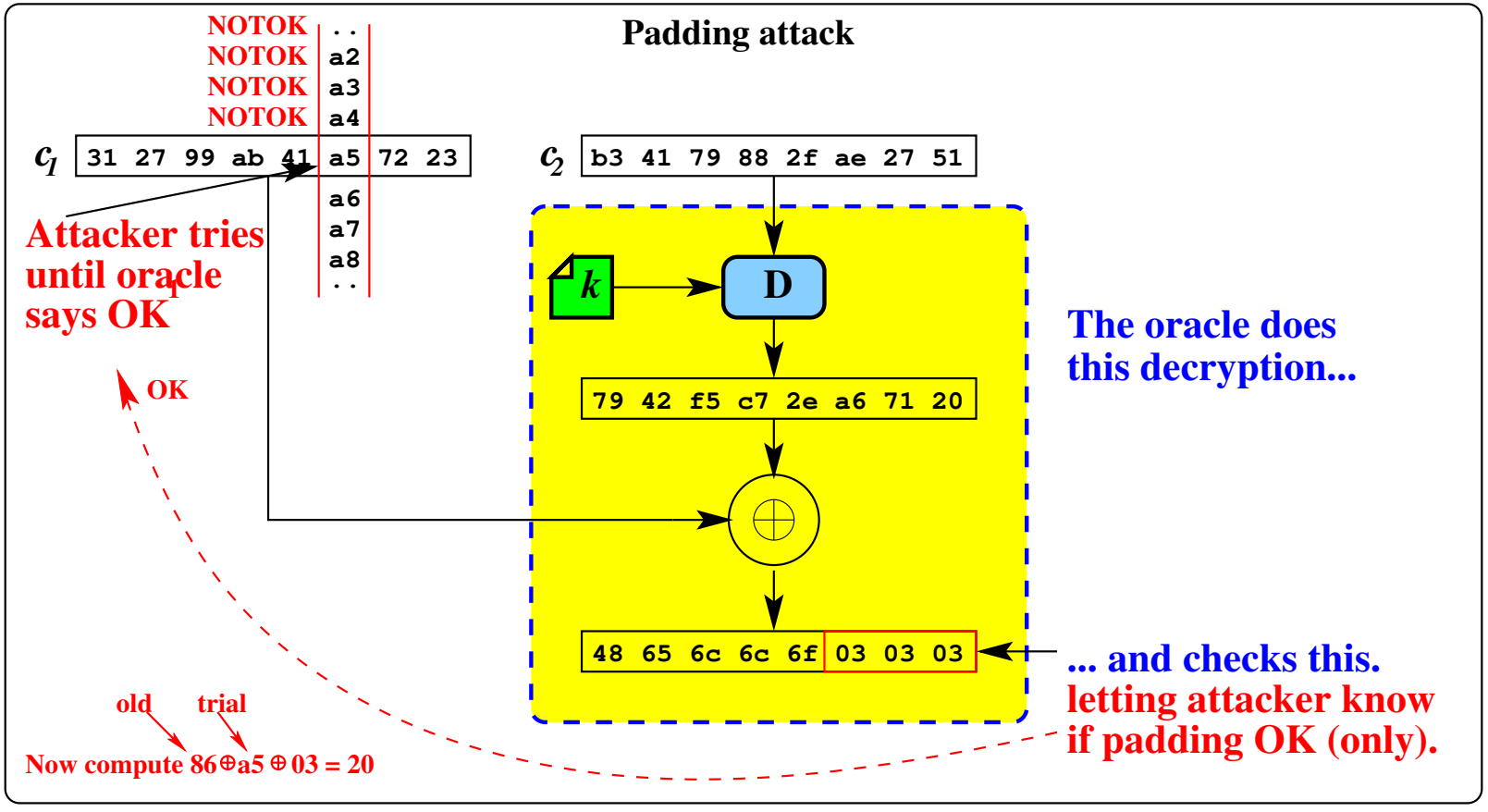


Since we know (now) the last byte (02), and the original last byte of c_1, we can set the last byte to anything we want.

We try all the second-to-last values in c_1, and uncover a second byte.

Using the oracle in an attack...

Attacker discovers third-to-last byte...

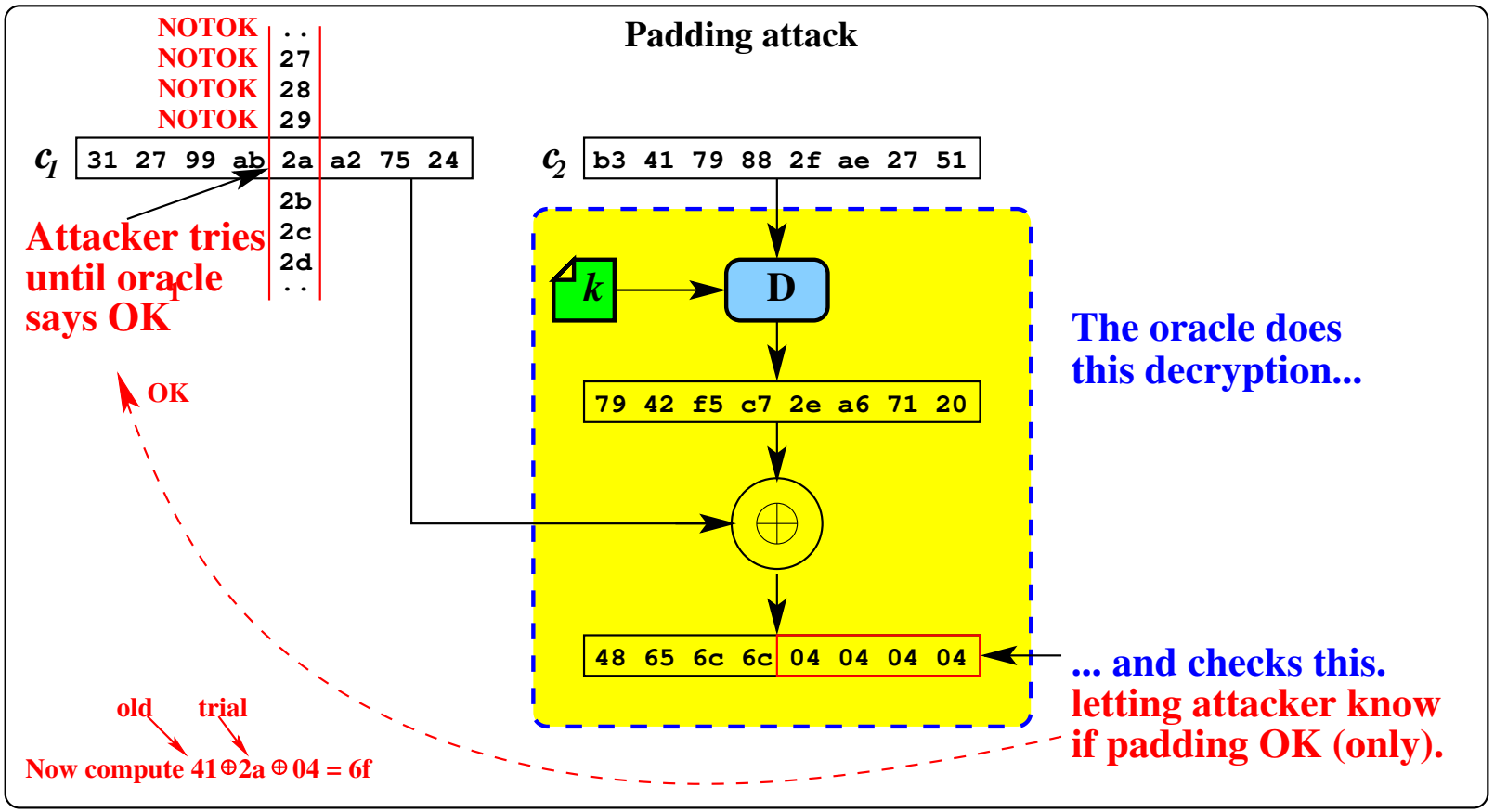


Since we know (now) the last two bytes (`02 02`), we can set the last two bytes to `03 03`.

Now we try all the third-to-last values in c_1 and uncover `20`.

Using the oracle in an attack...

Attacker discovers fourth-to-last byte...



Since we know (now) the last three bytes (`20 02 02`), we can set the last three bytes to `04 04 04`.

Now we try all the fourth-to-last values in c_1 and uncover `6f`.

Using the oracle in an attack...

Attacker discovers all bytes...

The attacker keeps moving through the block, and has to try a maximum of 255 trials for each byte recovered, so this is an $\mathcal{O}(n)$ attack, where n is the number of bytes in the block.

This attack can be avoided if...

- There is no oracle (i.e. the receiving code does not give any indication if the padding is correct or not)
- CFB is used instead.
- A different padding scheme is used...

That is it - a little aside into cracking that makes use of much of what we have learned.