GSM: WE CAN HEAR EVERYONE NOW!

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AGENDA

Topic: Vulnerability in GSM and generating an indicator to exploit it

- Section 1: Intro to GSM
- Section 2: Concept Overview
- Section 3: Test Lab Setup & Demonstration
- Section 4: Cellular Security Discussion

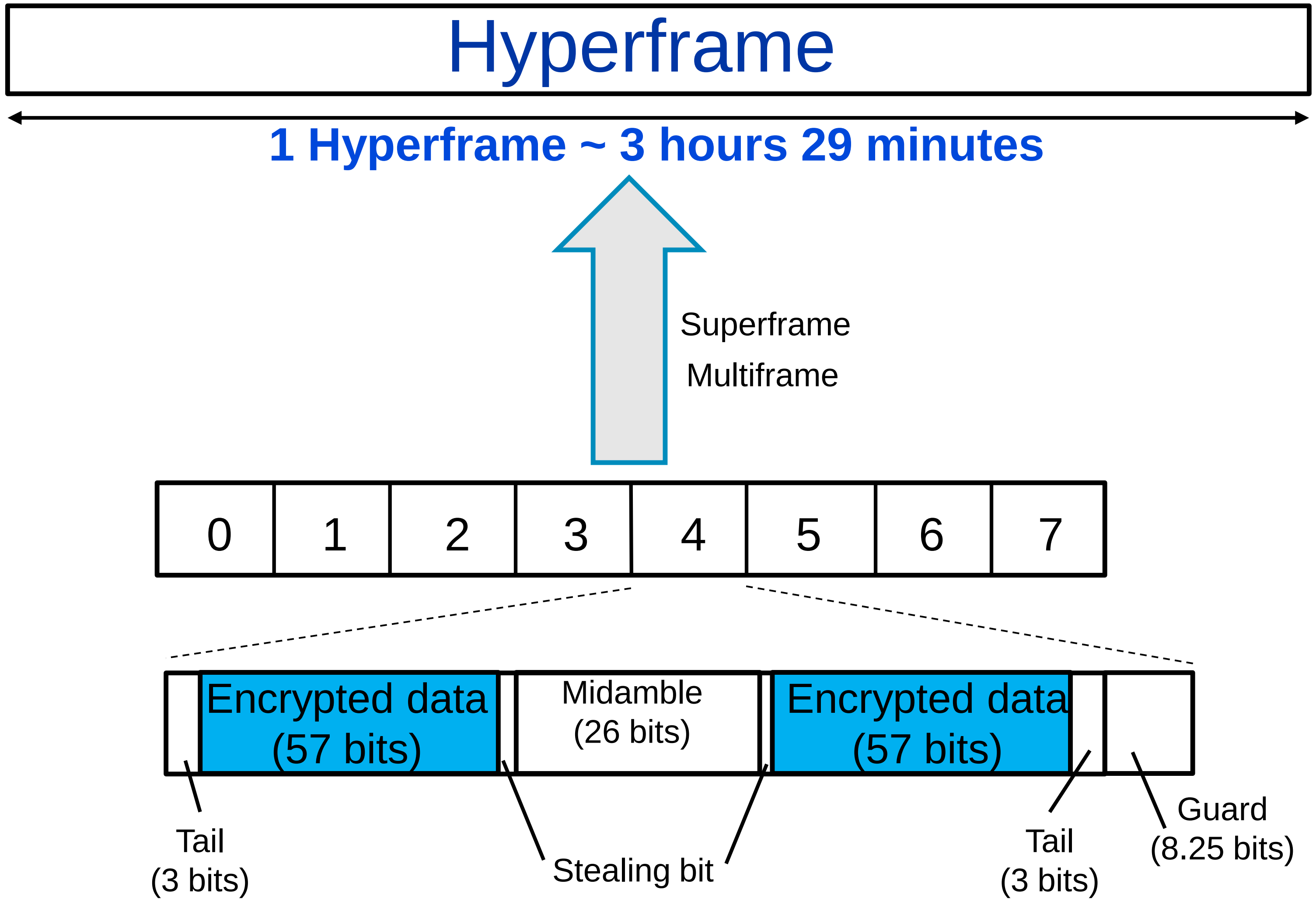
Introduction To GSM

GSM Introduction

- Concept for GSM (digital) started in the late 1980s
- Major improvement over AMPS (analogue)

- GSM Security has several design issues
  - Support for key sizes <= 64 bits
  - Encrypted data contains redundancy
    - Error control coding before ciphering

GSM Introduction



Hyperframe

- Contains 2,715,648 frames

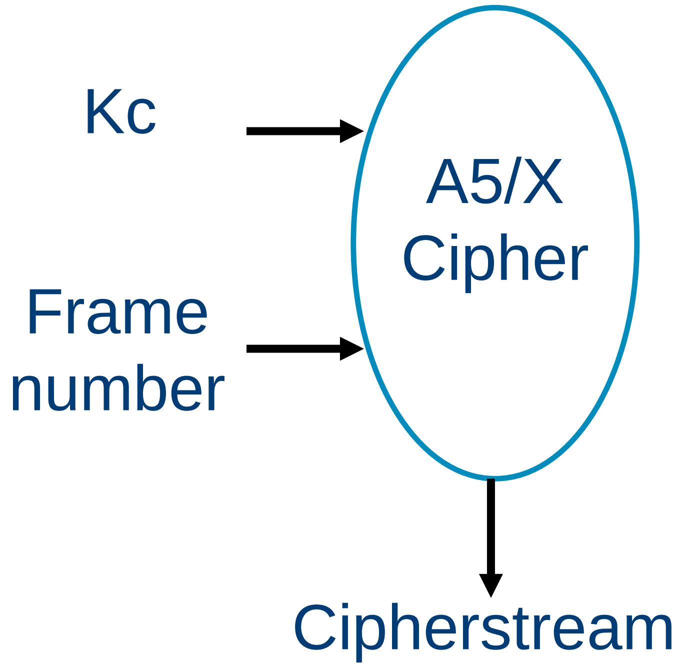
Frame

- Contains 8 timeslots

Timeslot

- Contains 114 encrypted data

GSM Introduction



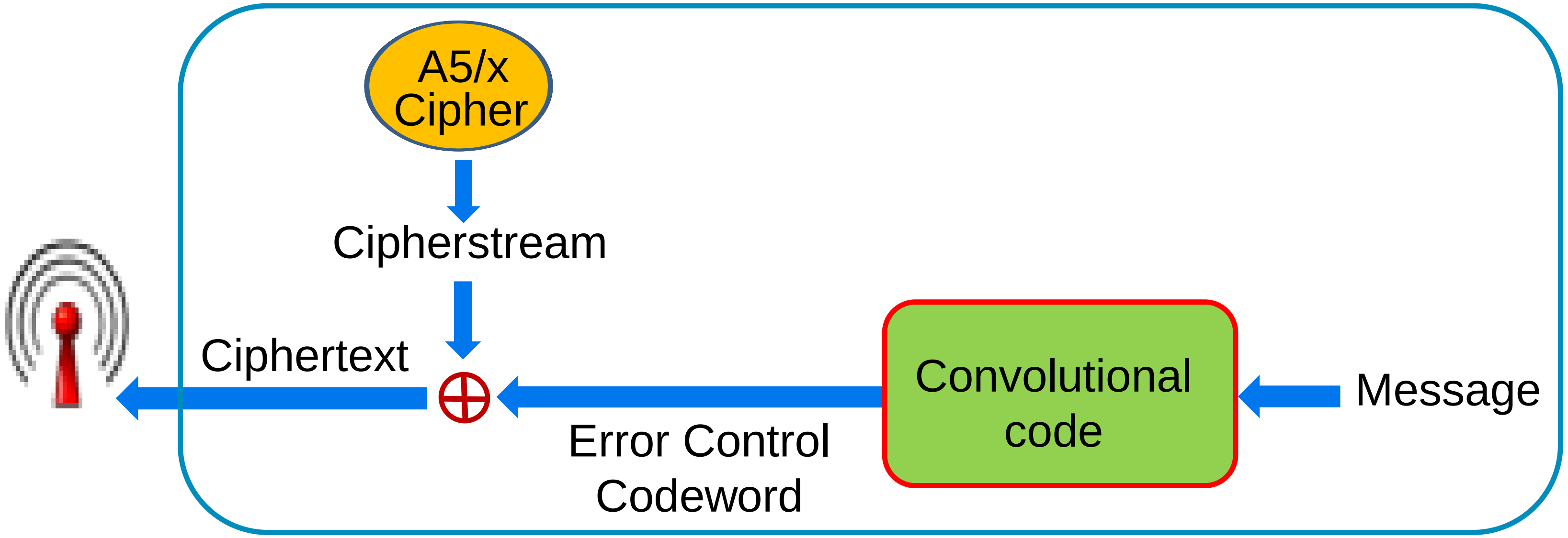
GSM based on symmetric encryption

- Specified ciphers: A5/1, A5/3 & A5/4
  - A5/1 up to 64 bit key
  - A5/3 up to 64 bit key
  - A5/4 up to 128 bit key
  - Note: A5/2 disallowed in 2000's

- NIST guidance: 112 bit security strength
  - "The use of keys that provide less than 112 bits of security strength for key agreement is now disallowed"

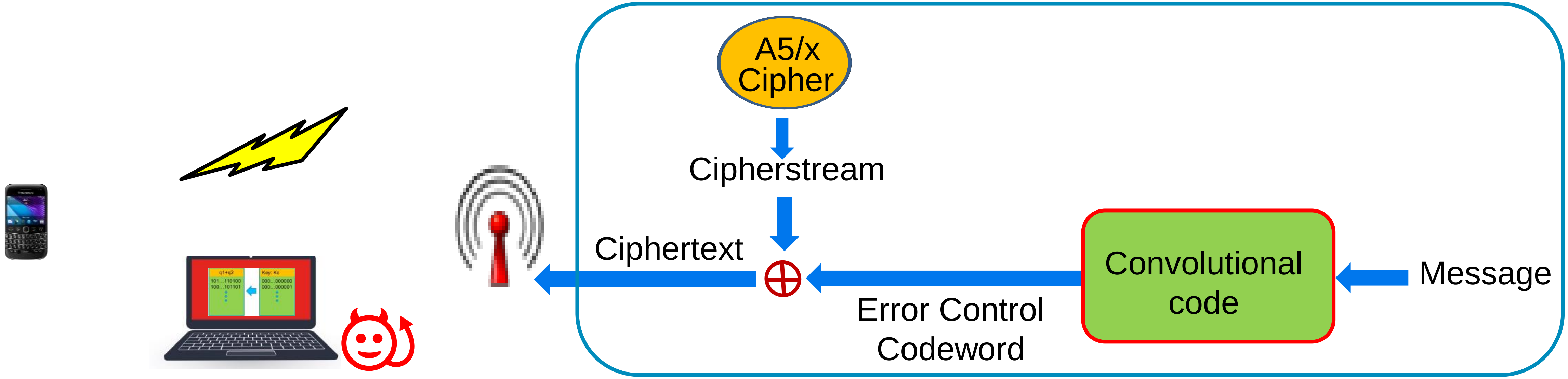
Concept Overview

Concept Overview



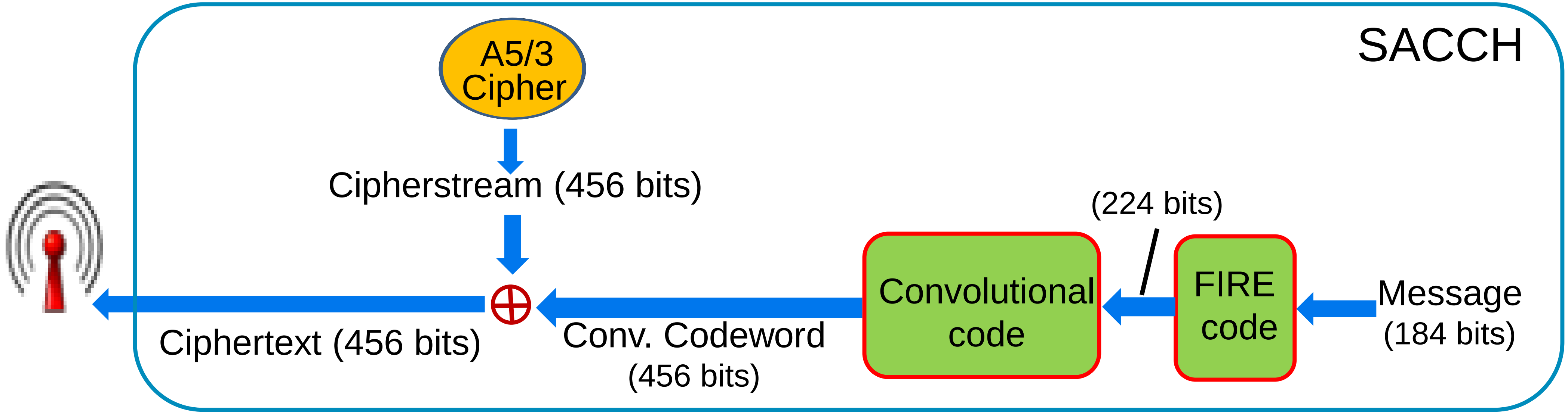
- Typical GSM Channel Structure with A5/1
  - Encryption
    - Key maximum 64 bits length
  - Convolutional error control code
    - Intended to combat noise from wireless channel
    - Attack uses code to identify cipherstream “noise”

Concept Overview



- High level view of attack
  - Capture GSM packet
  - Compute a cipherstream/key indicator
    - Use convolutional code parameters
  - Use indicator with a Rainbow table to identify ciphering key
    - Use indicator as a fingerprint for ciphering key

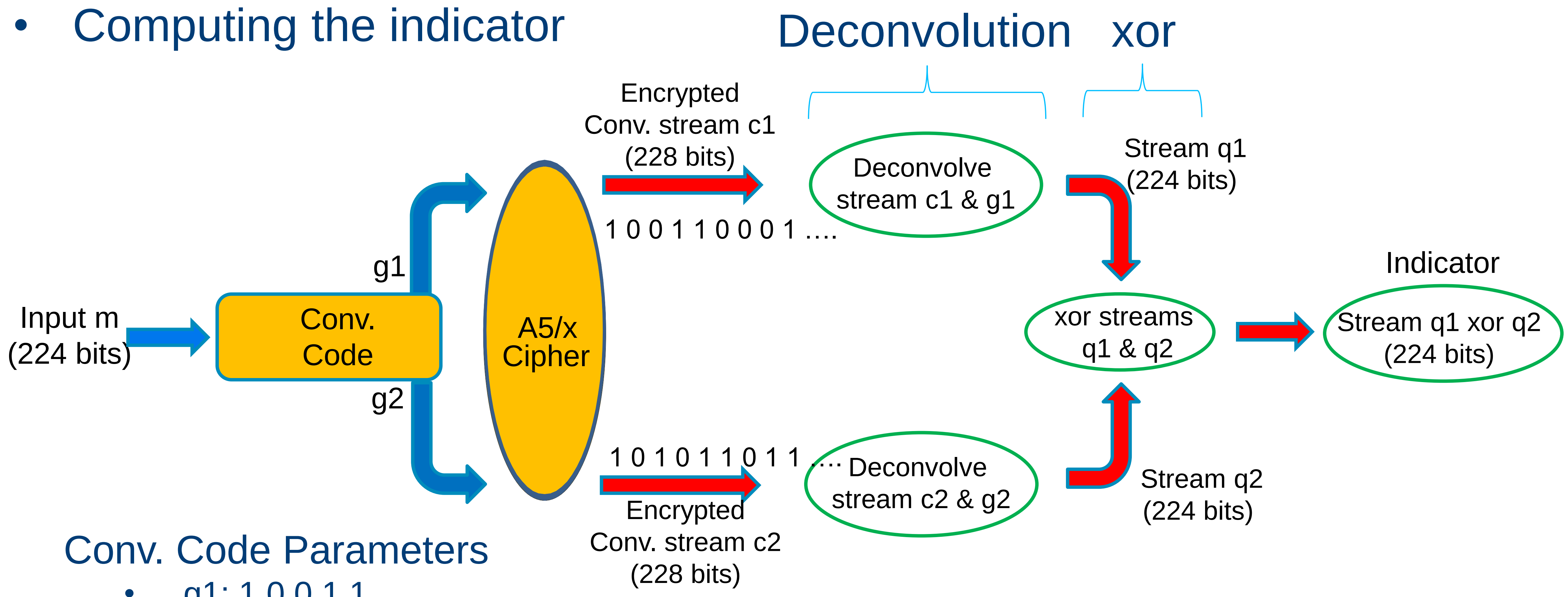
Concept Overview



- Demonstration uses SACCH control channel
  - Compromise of SACCH also compromises voice (same key)
  - Works for any SACCH message
    - Indicator/fingerprint is independent of the message
    - Knowledge of plaintext is not needed

Concept Overview

- Computing the indicator



Conv. Code Parameters

- g1: 1 0 0 1 1
- g2: 1 1 0 1 1

Concept Overview

- The indicator “q1 xor q2” is
  - Computed using the full convolutional codeword
    - Need 4x114 bursts
  - Independent of SACCH message
    - Fully determined by 1)The cipher stream and 2) Convolutional code
  - Full indicator length 224 bits
    - More than sufficient to identify a 64 bit key

Test Lab Setup & Demonstration

Hardware

- Various unlocked cellular devices
- 2G compliant Programable SIM cards
- PC SmartCard reader/writer
- Ettus Research N210 WBX
- Mini GPS ref. clock
- AirSpy SDR
- Various antennas

Software

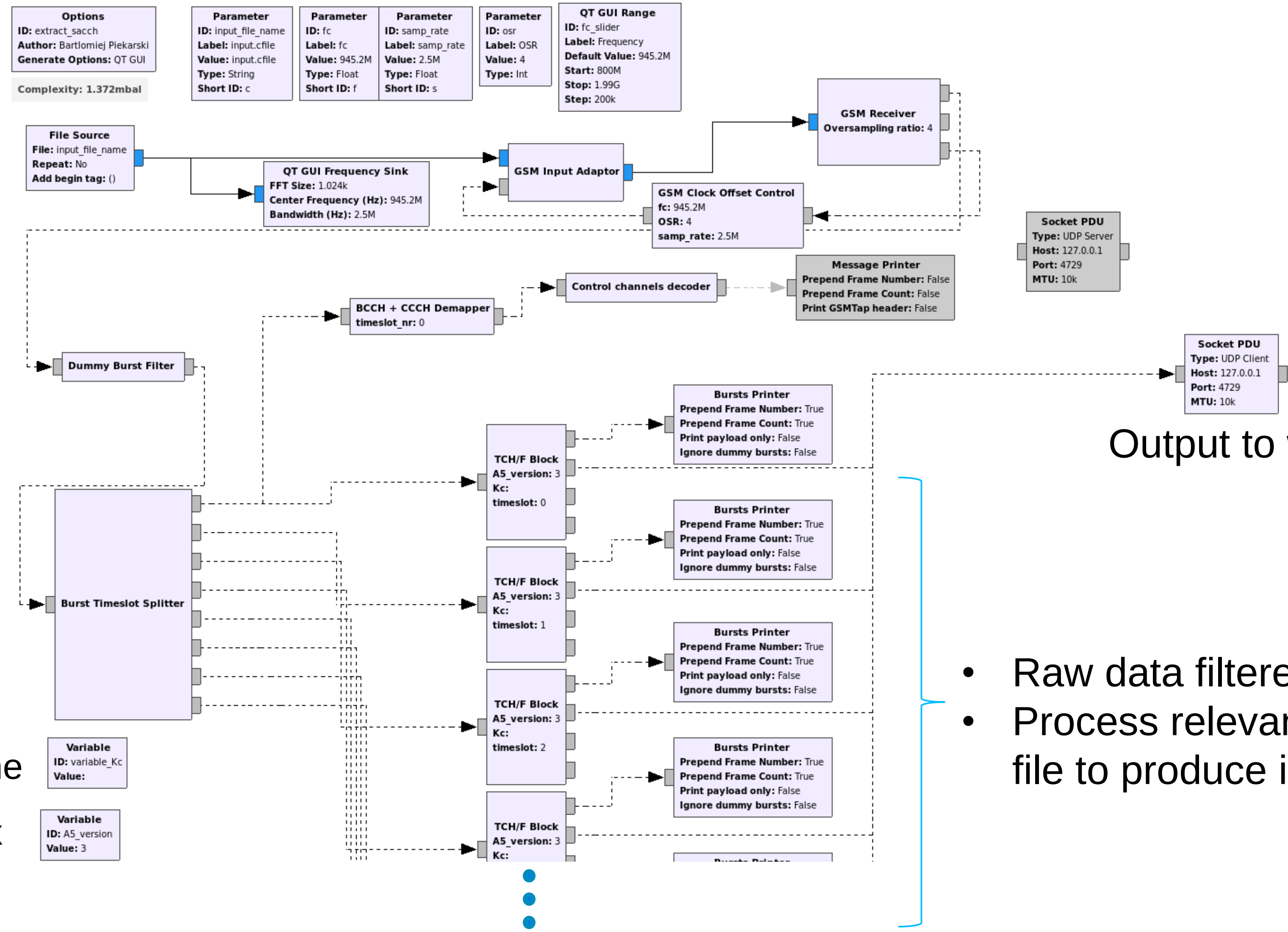
- RangeNetworks SDMN 7.0.4
- RangeNetworks OpenBTS 7.0.4
- PySIM
- GNU Radio 3.7.0
- GR-GSM
- GNU Octave 5.1

Lab Configuration

- All GSM testing run under RF isolation
- Cipher Mode configured for A5/3
- SACCH random neighbor protection enabled
- Random padding filler protection enabled

GR-GSM Configuration

Opening file, parsing, GSM signal processing



Output to wireshark

Kc/None

A5/x

- Raw data filtered into files.
- Process relevant timeslot file to produce indicator

Considerations in Mounting Attack

- Small key size: A5/1 & A5/3
  - Key length up to 64 bits
  - NIST guidance: 112 bit security strength for key agreement

- Rainbow table computation
  - Estimates based on 1 rig (4x NVIDIA GTX1080) proof-of-concept using opencl
  - A5/1, 64 bit key: Obtain 10% coverage using 500 rigs for 200 days
  - A5/3, 1 epoch, 64 bit key: Obtain 10% key coverage using 500 rigs for 263 days

Cellular Security Discussion

Cellular Security

- Indicator attack possible in GSM voice:
  - Small key size (e.g. At most 64 bits for A5/1 & A5/3)
    - Up to 64 bit key size for A5/1 & A5/3
    - NIST guidance: 112 bit security strength for key agreement
  - Ciphering performed after error control coding

- Additional attacks on GSM include:
  - Karsten Nohl (DEFCON 2010) “Attacking phone privacy”
  - Barkan et al. 2006 “Instant Ciphertext-only Cryptanalysis of GSM encrypted communication”
  - False Basestation attacks

Cellular Security

- Beyond GSM into 3G-to-5G:
  - Reduced security risk
  - Minimum encrypting key size of 128 bits
  - Error control coding applied **after** encryption not before

- Cellular industry actively studying solutions for GSM security
  - 3GPP TR 33.809 v0.5.0 “Study on 5G Security Enhancements against False Basestations”

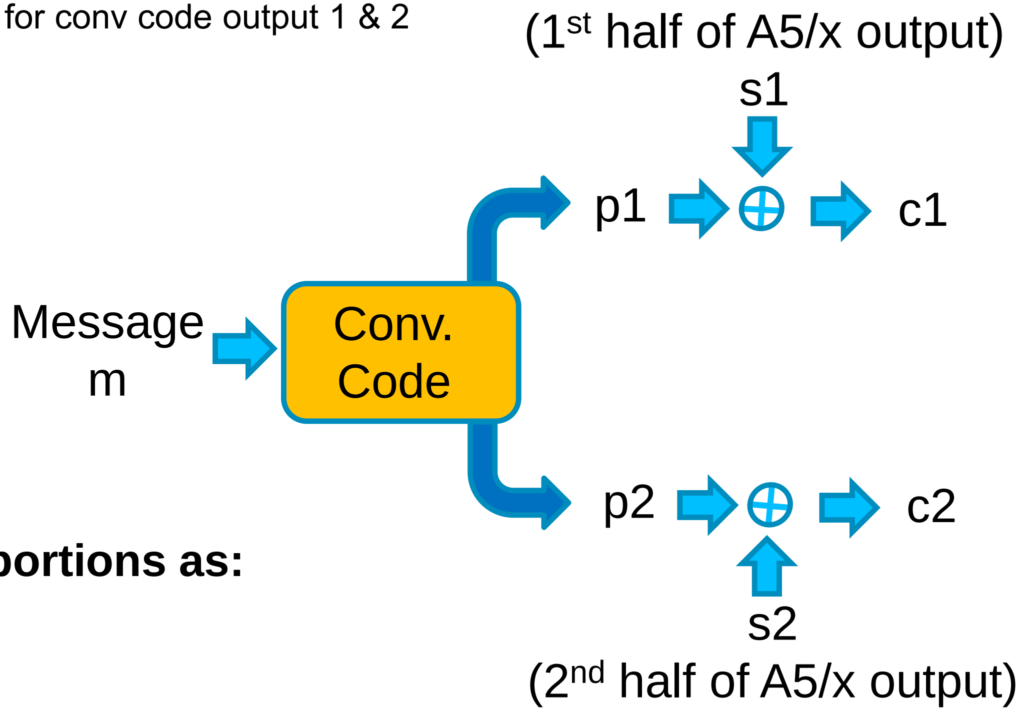
Q&A
Thank You

Appendix

Appendix

Consider the addition of the A5/x cipherstream to the codeword

- Separate cipherstream into portion xor'd for conv code output 1 & 2
- Let output 1 cipherstream be: s1
- Let output 2 cipherstream be: s2



Denote the resulting ciphertext portions as:

- c1 = s1 + p1 = s1 + m*g1
- c2 = s1 + p2 = s2 + m*g2

Appendix

The key to the attack is that the ciphertext portions can also be divided by g1 & g2 respectively for quotient q1 & q2

- C1 = s1 + p1 = s1 + m*g1 = (q1*g1 + r1) + m*g1
- C2 = s2 + p2 = s2 + m*g2 = (q2*g2 + r2) + m*g2

Rearranging c1&c2 we can now write

- C1 = (q1*g1 + r1) + m*g1 = (q1 + m)*g1 + r1
- C2 = (q2*g2 + r2) + m*g2 = (q2 + m)*g2 + r2

By deconvolving the ciphertext c1&c2 by g1&g2 respectively we can product the quotients

- (q1+m)
- (q2+m)

Adding these quotients generates (q1+q2) which is independent of the “m” :

- (q1+m) + (q2+m) = (q1+q2)