The Sources of Randomness in Smartphones with Symbian OS

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Outline

- Basics on random number generation
  - True- & pseudo- random number generators
  - Specifics of mobile devices
- Analysis of selected sources on Nokia N73
  - Entropy estimation
  - Microphone input
  - Camera input

- Practical pseudorandom number generator
  - Performance comparison

Basics on random number generation

- Random data in cryptography
  - Cryptographic keys, padding values, nonces, etc.
  - Quality and unpredictability is critical
- Generating truly random numbers
  - Based on nondeterministic physical phenomena
    - Radioactive decay, thermal noise, etc.
  - In deterministic environments hard and slow
- Generating pseudorandom numbers
  - Based on deterministic algorithm
    - Short input (seed) – truly random data
    - Output – pseudorandom data, computationally indistinguishable from truly random data
- Quality assurance – statistical testing

Specifics of mobile devices

- True random number generator
  - Quality strongly dependent on source of randomness
    - Possibility of influencing by attacker
  - General purpose computer systems
    - Many sources exist (hardware/software based, user inputs)
  - Mobile devices
    - Typically located only inside the chip (SIM card)
- Mobile device-dependent sources of randomness
  - Based on specific HW components of device
    - Microphone, digital camera, touchable LCD, battery level
  - Based on mobile nature of device
    - Information about current location, strength of transmitted signal (or other signal characteristics)
  - Better categorization
    - External & internal environment (+ mutual interactions)

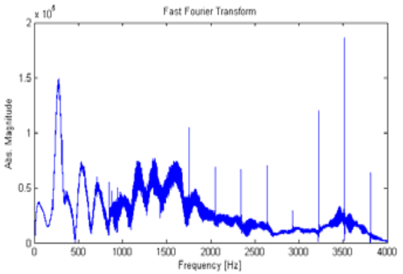
Entropy estimation

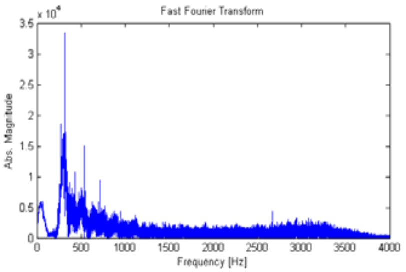
- Basic measure for randomness is called *uncertainty* or *entropy* (average-case)
  - $H_1(X) = -\sum_{x \in X} P_X(x) \log P_X(x)$
  - Sample *x* is drawn from random distribution *X* with probability $P_X(x)$
  - Logarithm base corresponds to units (2 => bits)
  - How many random bits is extractable per one time unit?
- Attacker can force source to produce most probable values => those values contains minimum entropy
- Better measure is *min-entropy* (worst-case)
  - $H_\infty(X) = \min_{x \in X}(-\log P_X(x)) = -\log(\max_{x \in X} P_X(x))$
  - Always less then or equal then Shannon entropy

- Selected device: smartphone Nokia N73
  - Symbian OS, JavaME, good camera, etc.

- Nokia N73 voice input
  - Embedded or hands-free microphone
  - Modulation method, sampling frequency => ~16 kB/s
    - 16-bit pulse coded modulation (a signed PCM)
    - Sampling a sound wave at frequency 8000 Hz

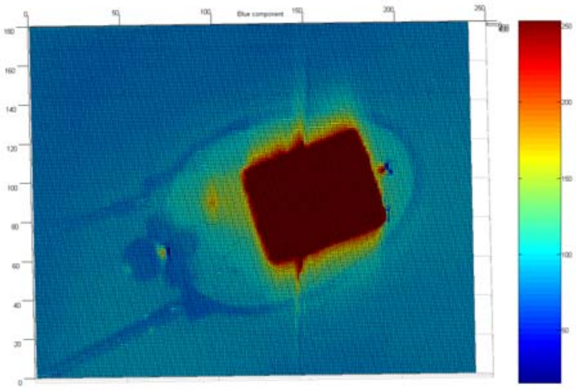
- Entropy in input sound signal
  - Focused on noise originated in microphone
  - Basic analysis (embedded/hands-free)
    - Fast/discrete Fourier transform => quality
    - Histogram analysis => upper bound





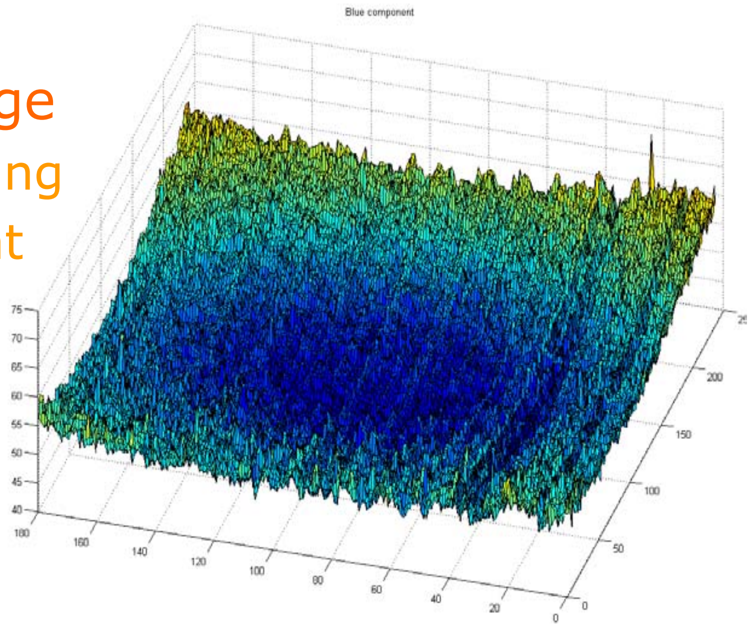
- Digital optical input devices
  - Array of semiconductor photo-sensors
    - Several chip designs
      - CCD, CMOS, EMCCD, ICCD, etc.
    - Different sensitivity, noise level, exposure time
  - More then 6 sources of noise
    - Mostly thermal noise => sensitivity to temperature
      - Higher temp. == higher noise

- Nokia N73 uses CMOS based 3.2 Mpix camera
  - View finding instead of high-resolution picture
    - No post-processing
      - noise reduction, compression
    - Fast data acquisition (12 fps, ~1600 kB)
      - 1 frame, 240×180 pixels, ~130 kB
  - Closed camera cover
    - Defense against overexposure
  - Temperatures 5 °C to 45 °C



Camera input entropy estimation

- Systematic defects in camera image
  - Sensor technology & post-processing
  - Avg. value of blue color component
    - Hot pixels around borders
    - Significant rips in the rows
    - Centered circle rips
    - Different intensity towards centre



- Independency of pixels in image (& between images)
  - Matlab *corrcoef* cross-correlation function [OK]
    - Neighboring pixels & pixels in the same row
  - Matlab auto-correlation and FFT/DFT [OK]
    - Vector of values taken in time from single pixel (12 fps)
  - NIST test battery [green component always passed]
    - Bit-streams generated from R/G/B pixel values

Practical pseudorandom number generator

- Pseudorandom number generator
  - Often based on cryptographic primitives (AES, SHA-xxx)
    - Serve as fast entropy extractors
    - No mathematical guarantee of security
  - Amount of raw data from sources limited by the performance of mobile device

- Performance comparison (tested on SHA-1)
  - Nokia N73 (Symbian v9.1) ~ 2200.00 kB/s
  - Nokia N73 (JavaME) ~ 426.00 kB/s
  - Sony-Ericsson k750i (JavaME) ~ 84.00 kB/s
  - Nokia 6230 (JavaME) ~ 67.00 kB/s
  - Nokia 6021 (JavaME) ~ 4.65 kB/s

Conclusion

- Mobile device contains several randomness sources
  - Some low-level sources have no sufficient precision (API restrictions) or have a slow refresh frequency
    - Battery level and signal strength (only ten values scale)
    - GPS position (only one measurement per second)
  - Other sources seems to be suitable
- Analysis of selected sources on Nokia N73
  - Microphone & camera input have great potential
    - Big throughput and inherently presented internal noise
    - Min-entropy (upper bound) is 2/4 bits per audio sample/subpixel
  - Our analysis found several defects in camera input
    - Due to sensor technology & post-processing
    - Statistical tests of random data from camera noise promising
  - Symbian OS performance significantly higher than JavaME
    - Possibility to extract entropy from high throughput sources