Lightweight Cryptography

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CS 665 (Spring 2023)

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Project Inspiration

Ascon

1. Initialization
2. Associated Data
3. Plaintext
4. Finalization

Research Questions

1. *When does it make sense to utilize LWC?*

2. *How can we benchmark & visualize respective results?*

Key Terms

- Combinations vs. permutations
- Cryptographic nonce
- Ephemeral secrets
- Round count

Managing Complexity

	Language Choice	Hardware Decisions	System Constraints
1	JavaScript Framework	≥ Web Server	Networking
2	Ruby & Python	≈ Raspberry Pi	Device Storage
3	C / C++	≤ Arduino	Memory + Message Size

Hash-based Message Authentication Codes

- Hash function
- Block vs. stream cipher
- Known or shared key
  - Message integrity
  - Authentication

- [Securing Stream Ciphers (HMAC) - Computerphile]
  - Dr Mike Pound

⚠️

- Checksum similarity
  - [message | hashed {m}]
- Length extension attack
  - message | hashed {key/m}

```ruby
# Solomon Himelbloom
# CS 665 (Final Project)
# 2023-04-07
#
# Simple hashing function with demo string.

require 'digest'
require 'openssl'

class LWC
  def initialize
    @hash = Digest::SHA256.new
  end

  def hash_string(plaintext)
    @hash.hexdigest(plaintext)
  end

  def generation
    key = 'key'
    data = 'The quick brown fox jumped over the lazy dog.'
    hmac = OpenSSL::HMAC.hexdigest(OpenSSL::Digest.new('sha256'), key, data)
    puts hmac
  end
end

input = "Lightweight Cryptography"

lwc = LWC.new
puts lwc.hash_string(input)
lwc.generation
```

(e.g. Ruby)

Demo

Static Site Generation

lightweight-cryptography.pages.dev

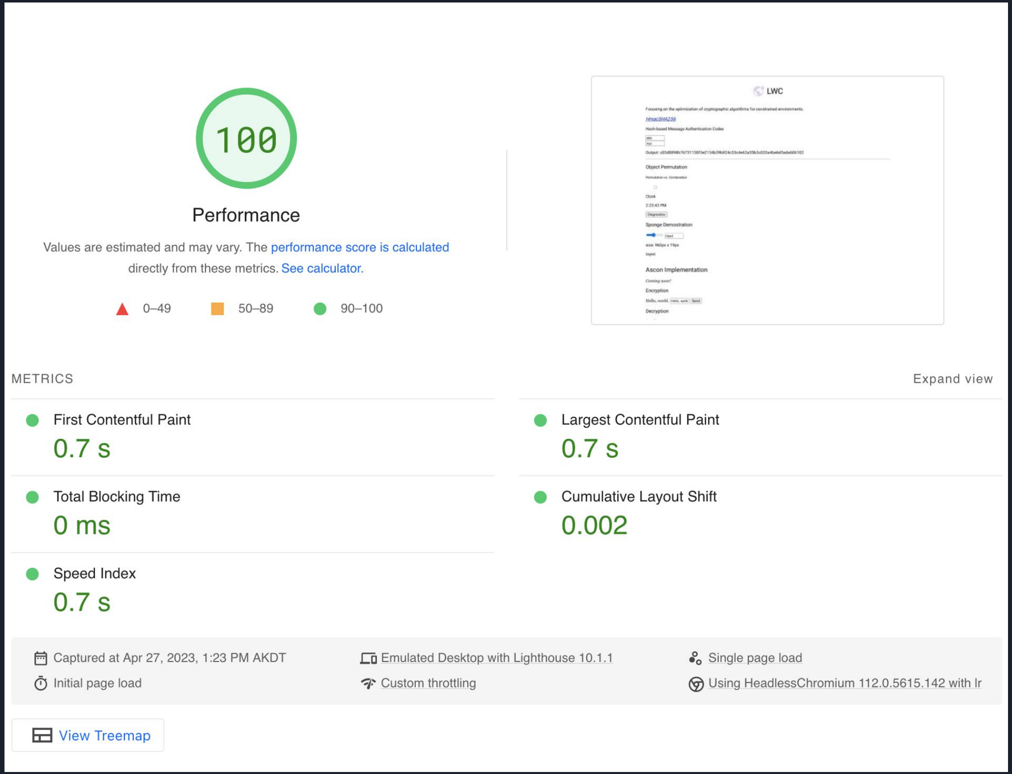
- SvelteKit & Cloudflare Pages
  - GitHub Repository
- Security considerations
  - User input (sanitized?)
  - Status codes + redirects
  - External packages
- Benefits
  - Routing for pages

Basic Analysis

Initial System Benchmarks

- **Arduino Uno Rev3** (SHA-256 Baseline / Rhys Weatherley's LWC Primitives)
  - Hashing: 167.01µs per byte, 5987.68 bytes per second
  - Finalizing: 10721.19µs per op, 93.27 ops per second
  - HMAC Reset: 10722.48µs per op, 93.26 ops per second
  - HMAC Finalize: 32196.03µs per op, 31.06 ops per second
- **Ruby** (Initial Hash + HMAC)
  - real 0m0.142s | user 0m0.101s | sys 0m0.040s
- **Web Version**
  - Svelte + Cloudflare Pages (w/ variable page load times)
  - Jupyter Notebook (pyascon → pictured right)

```
[ ] %time
    demo_aead('Ascon-128')

    CPU times: user 3 µs, sys: 0 ns, total: 3 µs
    Wall time: 7.15 µs
    === demo encryption using Ascon-128 ===
    key:        0xd27a1d2c71997eb418aa2d42d1108ddb (16 bytes)
    nonce:      0xa3accc404eae1c05248c1923abf2c006 (16 bytes)
    plaintext:  0x6173636f6e (5 bytes)
    ass.data:   0x4153434f4e (5 bytes)
    ciphertext: 0x9ac7c12a76 (5 bytes)
    tag:        0x4dc4d2861ca509f743c156b7df3abc4d (16 bytes)
    received:   0x6173636f6e (5 bytes)

[ ] %time
    demo_hash("Ascon-Hash")

    CPU times: user 4 µs, sys: 0 ns, total: 4 µs
    Wall time: 7.15 µs
    === demo hash using Ascon-Hash ===
    message: 0x6173636f6e (5 bytes)
    tag:     0x02c895cb92d79f195ed9e3e2af89ae307059104aaa819b9a987a76cf7cf51e6e (32 bytes)

[ ] %time
    demo_mac("Ascon-Mac")

    CPU times: user 3 µs, sys: 0 ns, total: 3 µs
    Wall time: 6.91 µs
    === demo MAC using Ascon-Mac ===
    key:     0xae9dd032adc49898cb50178529ee482c (16 bytes)
    message: 0x6173636f6e (5 bytes)
    tag:     0x4a264d9c4f3f8b5b5909f35c56e9142c (16 bytes)
```




```
real	0m0.002s
user	0m0.002s
sys	0m0.000s
[ec2-user@ip-172-31-15-70 netrun]$ time ./a.out
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528

real	0m0.002s
user	0m0.002s
sys	0m0.000s
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real	0m0.002s
user	0m0.002s
sys	0m0.000s
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.394s
user	0m0.362s
sys	0m0.032s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.389s
user	0m0.320s
sys	0m0.068s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.396s
user	0m0.336s
sys	0m0.059s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.399s
user	0m0.342s
sys	0m0.056s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.390s
user	0m0.365s
sys	0m0.025s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.392s
user	0m0.326s
sys	0m0.066s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
[ec2-user@ip-172-31-15-70 netrun]$ time g++ SHA256.cpp; ./a.out

real	0m0.391s
user	0m0.337s
sys	0m0.054s
SHA256('Lightweight Cryptography'): f7efb0761ca6f93f7c88c53a063eafbe021b5c2f4e86f4075159957455806528
```

📊 Data Collection Methodology

Next Steps
+ Lessons Learned

Retrospective

- Continue improving ease-of-use for common web tools
  - Systematic approach for individual tests
- Improved visualizations stemming from benchmarking tasks
  - CPU, memory utilization, & temperature
- Expanding towards smaller devices
  - Industrial control systems → IoT → sensor nodes → RFID
- Standing on the shoulders of…
  - Layers of abstraction
  - Historical examples
  - Giants!
- Start small, finish big

Works Cited

1. Christoph Dobraunig, Maria Eichlseder, Florian Mendel, and Martin Schläffer. 2021. Ascon v1.2: Lightweight Authenticated Encryption and Hashing. J. Cryptol. 34, 3 (Jul 2021). https://ascon.iaik.tugraz.at/index.html
2. Guido Bertoni, Joan Daemen, Michaël Peeters, and Gilles Van Assche. 2011. Cryptographic sponge functions. https://keccak.team/files/CSF-0.1.pdf
3. M. Rahman, S. Karnik, and S. Sarangerel. Lightweight Cryptography. Spring 2022 MIT 6.857: Computer and Network Security, Submitted Final Paper.
4. Lightweight Cryptographic Algorithms. Communications Security (ComSec) Lab, 2019-11-25. https://uwaterloo.ca/communications-security-lab/lwc.
5. R. Mishra, S. Dutta, M. Okade, and K. Mahapatra, "Substitution Permutation Network based Lightweight Ciphers with Improved Substitution Layers for Secure IoT Applications," 2021 2nd International Conference on Range Technology (ICORT), Chandipur, Balasore, India, 2021, pp. 1-6, doi: 10.1109/ICORT52730.2021.9581374.

📆 Upcoming:
⇒ Industry Events
⇒ NIST LWC News

Semester Security Paper Findings

2023.04.28 – *The Ascon Family for Lightweight Cryptography* (talk)

Summer '23 – Sixth Lightweight Cryptography Workshop (virtual)

Questions?