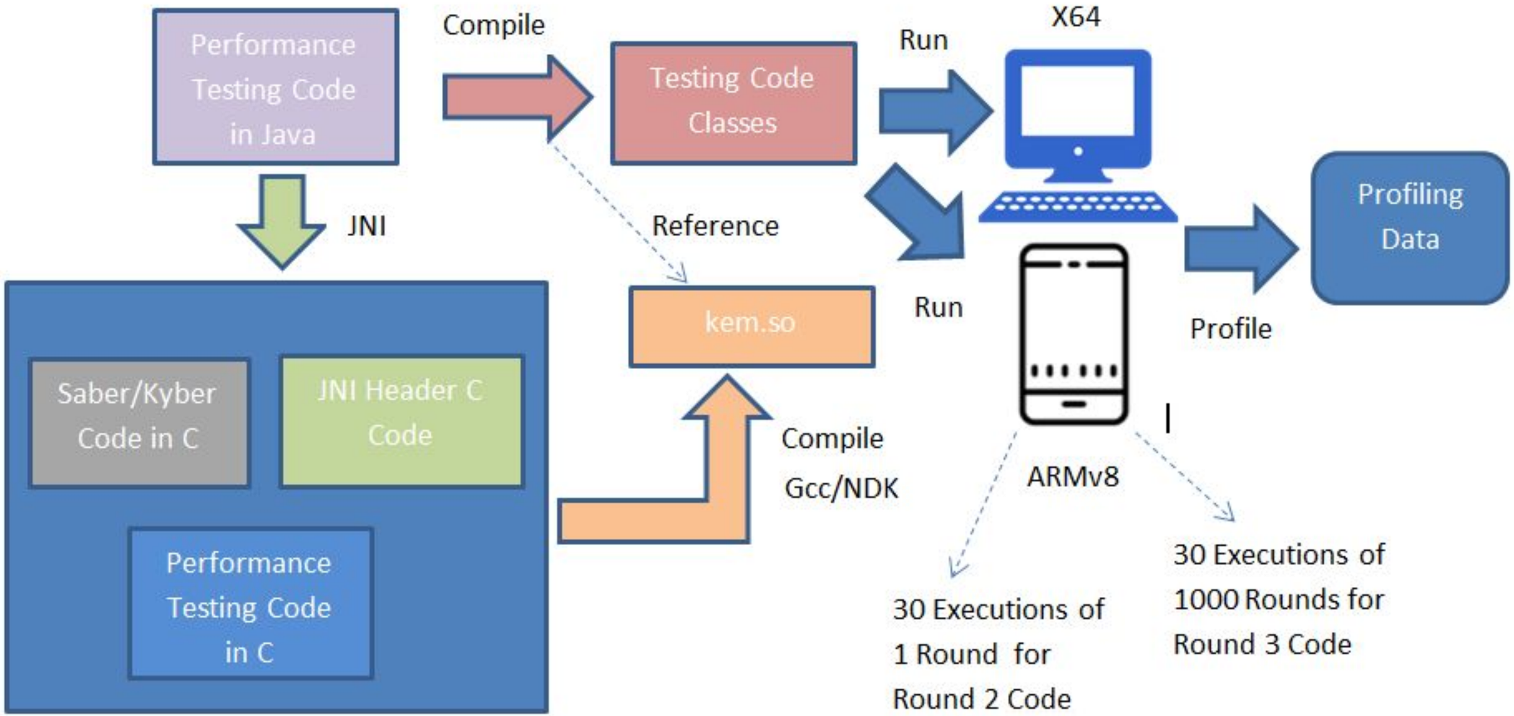
Saber Post-Quantum Key Encapsulation Mechanism (KEM): Evaluating Performance in Mobile Devices and Suggesting Some Improvements / Evaluating Kyber in post-quantum KEM in a mobile application

NIST PQC Conference 2021

Topics

- Saber/Kyber Testing Flow
- Saber Performance Tests Data
  - x64 versus ARM Architectures
- Kyber Performance Tests Data
  - x64 versus ARM Architectures

Saber/Kyber Test Flow



How were the tests done?

- Used standard version of both Saber/Kyber.
- Tests Characteristics:
  - Input: *Key Session Object (128 bytes).*
  - Output: *Profiling Data*
  - Code Sequence:
    - Call “indcpa_kem_keypair (byte[] pubKey, byte[] privKey)”.
    - Call “indcpa_kem_enc (byte[] message, byte[] pubKey)”.
    - Call “indcpa_kem_dec (byte[] encData, byte[] privKey) ”.
- Padding was necessary when data was not multiple of block size.

Algorithms Versions Evaluated - NIST Round 2 and 3

- Kyber1024
  - NIST security level: 5[1]
  - sk: 3168
  - pk: 1568
  - ct: 1568
- FireSaber
  - NIST security level: 5[1]
  - sk: 1664
  - pk: 1312
  - ct: 1472

[1] "Any attack that breaks the relevant security definition must require computational resources comparable to or greater than those required for key search on a block cipher with a 256-bit key (e.g. AES 256)." (NIST, 2017).

Saber Test Devices

- Mobile Device ARMv8
  - Android 10
  - RAM: 8GB
  - Octa-core (2x2.73 GHz Mongoose M5 + 2x2.60 GHz Cortex-A76 + 4x2.0 GHz Cortex-A55)
- PC
  - Ubuntu 20.04 LTS
  - RAM: 8GB
  - Intel(R) Core(TM) i7-6700 - 3,4GHz
  - 64 bits

- Security Level: ***FireSaber (AES-256)***

Saber - Average Time - x64 Architecture

- Round 2
  - KEY GENERATION:
    - 1458.00 μ seconds
  - ENCRYPTION:
    - 1584.04 μ seconds
  - DECRYPTION:
    - 382.43 μ seconds

- Round 3
  - KEY GENERATION:
    - 1970.18 μ seconds
  - ENCRYPTION:
    - 2435.74 μ seconds
  - DECRYPTION:
    - 574.68 μ seconds

* Round 2 had better performance

Saber - Average Time - ARM Architecture

- Round 2
  - KEY GENERATION:
    - 894.20 μ seconds
  - ENCRYPTION:
    - 753.70 μ seconds
  - DECRYPTION:
    - 211..09 μ seconds

- Round 3
  - KEY GENERATION:
    - 333.96 μ seconds
  - ENCRYPTION:
    - 355.25 μ seconds
  - DECRYPTION:
    - 128.25 μ seconds

* Round 3 had better performance

Saber - Bottlenecks - x64 Architecture

- Round 2
  - KEY GENERATION:
    - MatrixVectorMulti Function (81% Consumption)
  - ENCRYPTION:
    - MatrixVectorMulti Function (59% Consumption)
  - DECRYPTION:
    - InnerProd Function (95% Consumption)
- Round 3
  - KEY GENERATION:
    - MatrixVectorMulti Function (86% Consumption)
  - ENCRYPTION:
    - MatrixVectorMulti Function (68% Consumption)
  - DECRYPTION:
    - InnerProd Function (96% Consumption)

* MatrixVectorMulti and InnerProd are bottlenecks

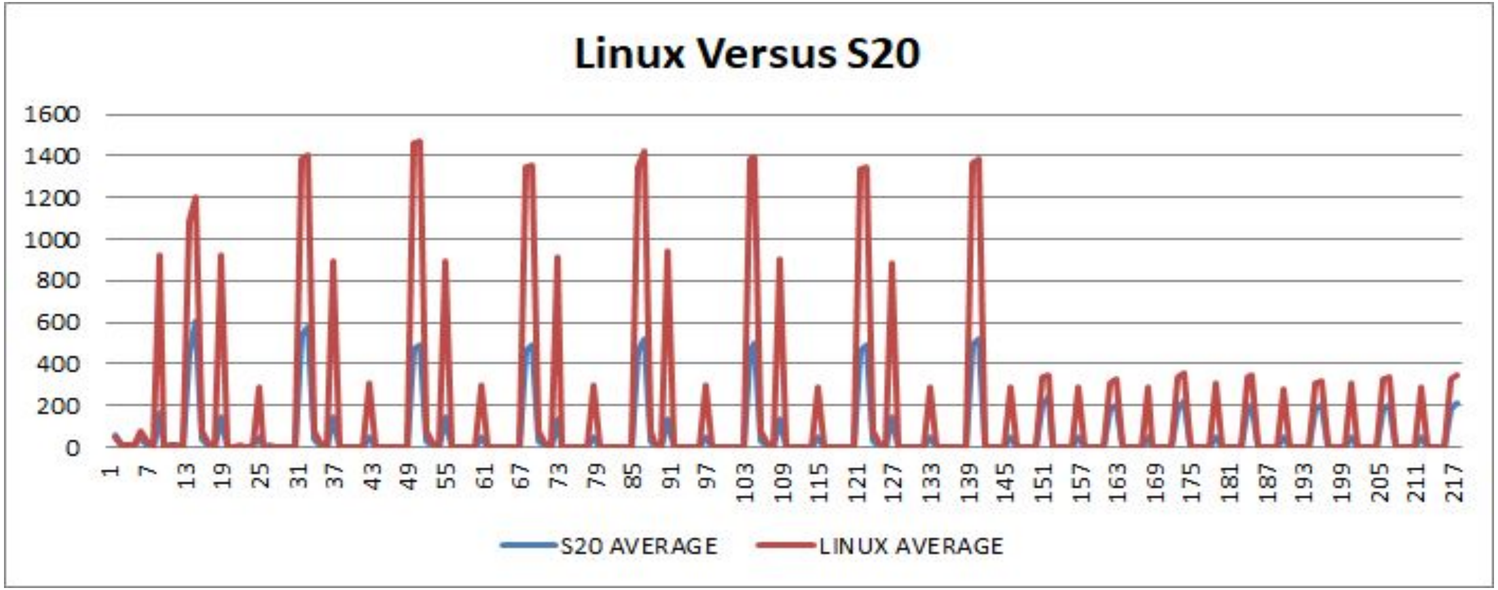
Saber - Bottlenecks - ARM Architecture

- Round 2
  - KEY GENERATION:
    - MatrixVectorMulti Function (67% Consumption)
  - ENCRYPTION:
    - MatrixVectorMulti Function (40% Consumption)
  - DECRYPTION:
    - InnerProd Function (88% Consumption)
- Round 3
  - KEY GENERATION:
    - MatrixVectorMulti Function (64% Consumption)
  - ENCRYPTION:
    - MatrixVectorMulti Function (55% Consumption)
  - DECRYPTION:
    - InnerProd Function (89% Consumption)

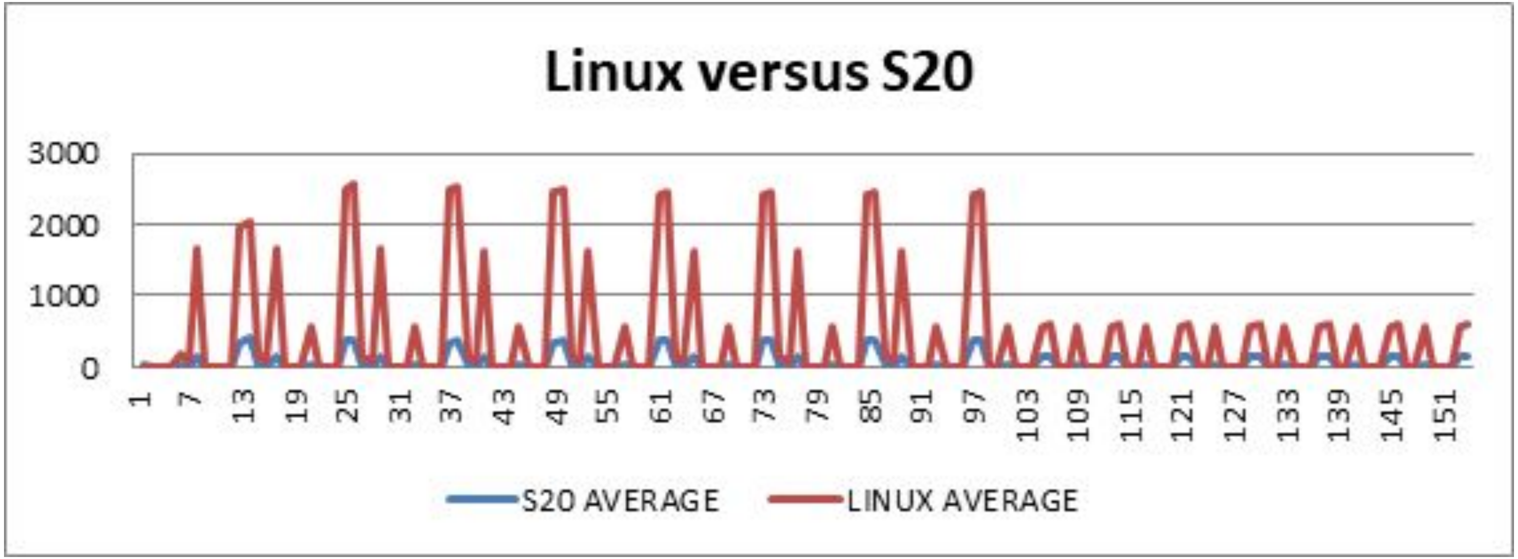
* MatrixVectorMulti and InnerProd are bottlenecks

* Consumption values were more balanced

Saber Round 2 - x64 versus ARM Architectures



Saber Round 3 - x64 versus ARM Architectures



- x64 better 4 times and ARM better 26 times

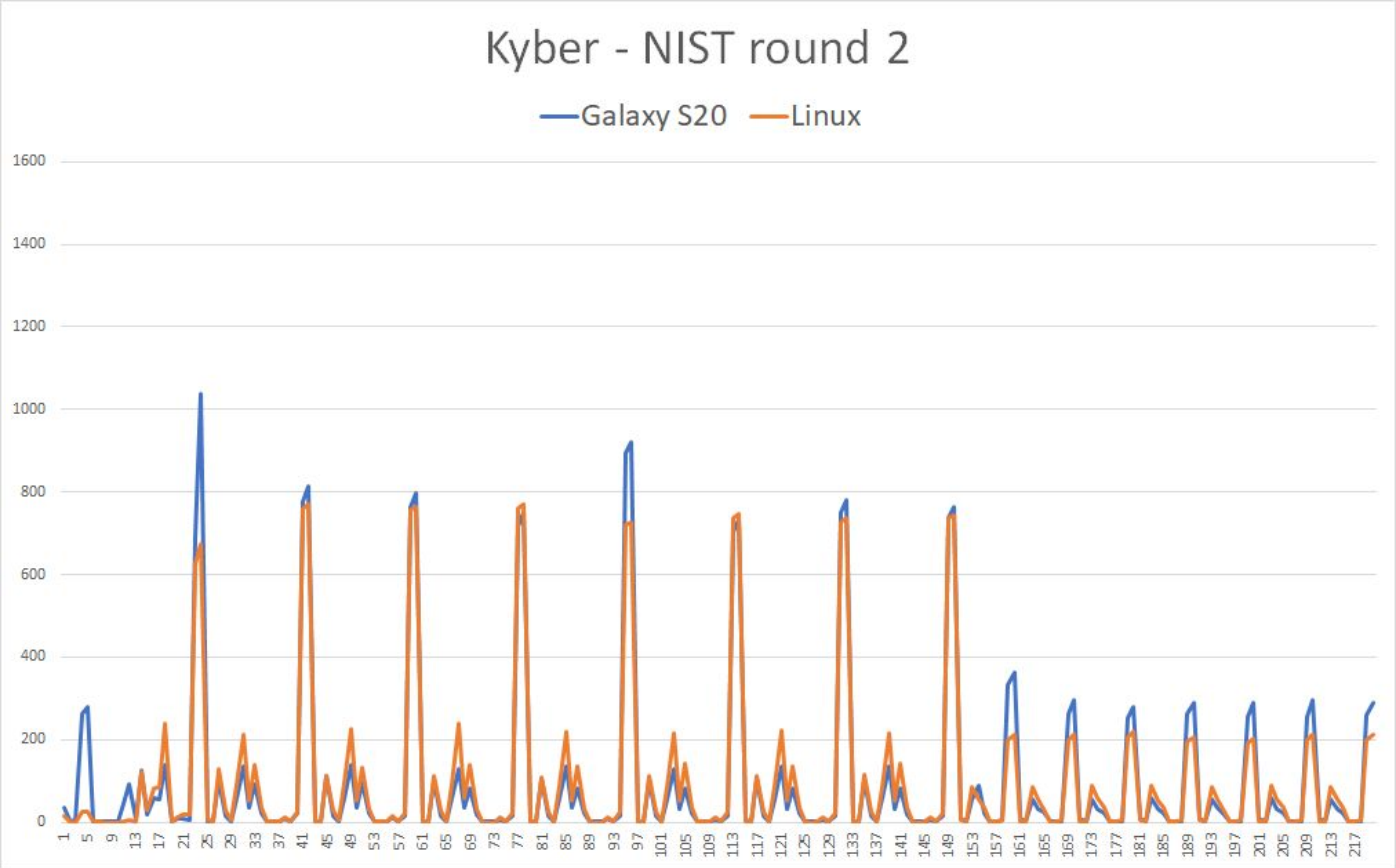
Saber Round 3 Code Improvement

- Improvement in MatrixVectorMulti Function
  - Use **shift operations** *instead of* **division by 2** on **karatsuba_simple** function that is inside *MatrixVectorMulti function.*
- What was better in performance?
  - Function had an improvement of ***3.26% compared to Round 3 original code***.
- Is improvement conclusive?
  - Tests showed better performance, however we can't affirm it's conclusive.
  - There are compilers that automatically change division by 2 to shift operations.
  - We suggest Saber team to evaluate this improvement and conclude if it really improved performance.

Kyber Test Devices

- Mobile Device ARMv8
  - Android 10
  - RAM: 8GB
  - Octa-core (2x2.73 GHz Mongoose M5 + 2x2.60 GHz Cortex-A76 + 4x2.0 GHz Cortex-A55)
- PC
  - Ubuntu 20.04 LTS
  - RAM: 8GB
  - Intel(R) Core(TM) i7-6700 - 3,4GHz
  - 64 bits

- Security Level: ***Kyber1024 (AES-256)***


Kyber - NIST round 2
Galaxy S20
Linux
1600
1400
1200
1000
800
600
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200
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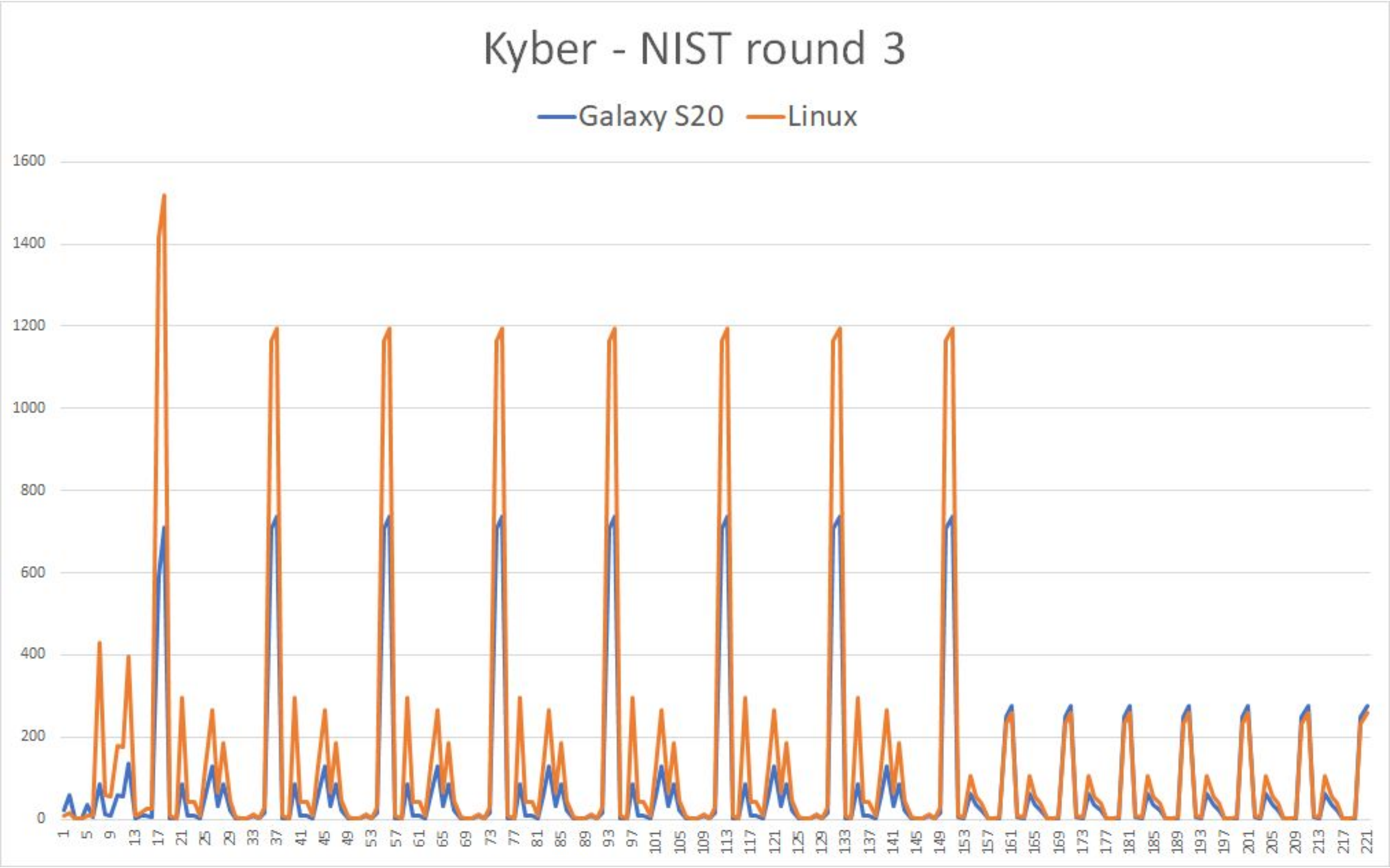

Kyber - NIST round 3
Galaxy S20
Linux
1600
1400
1200
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600
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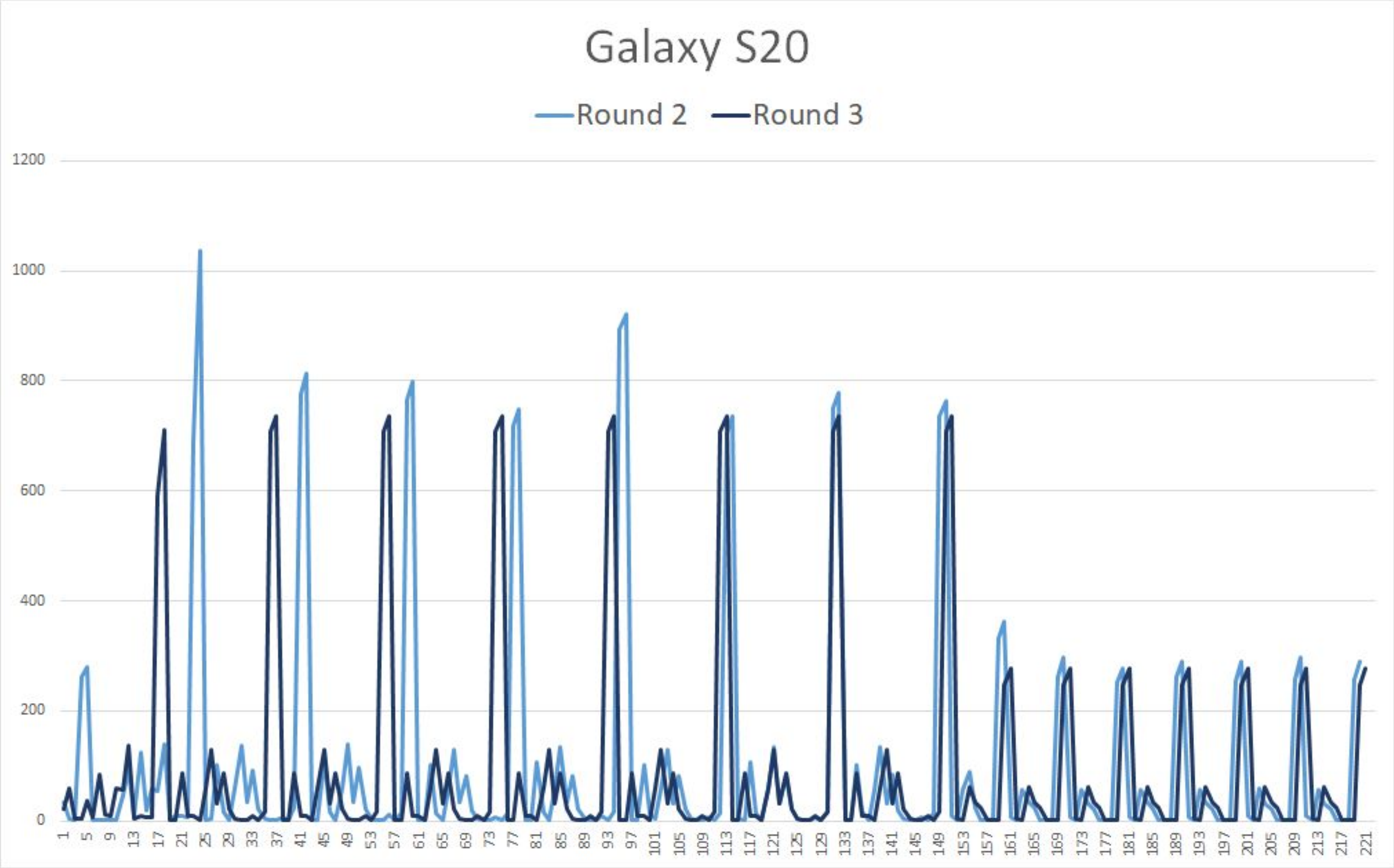
Galaxy S20
Round 2
Round 3
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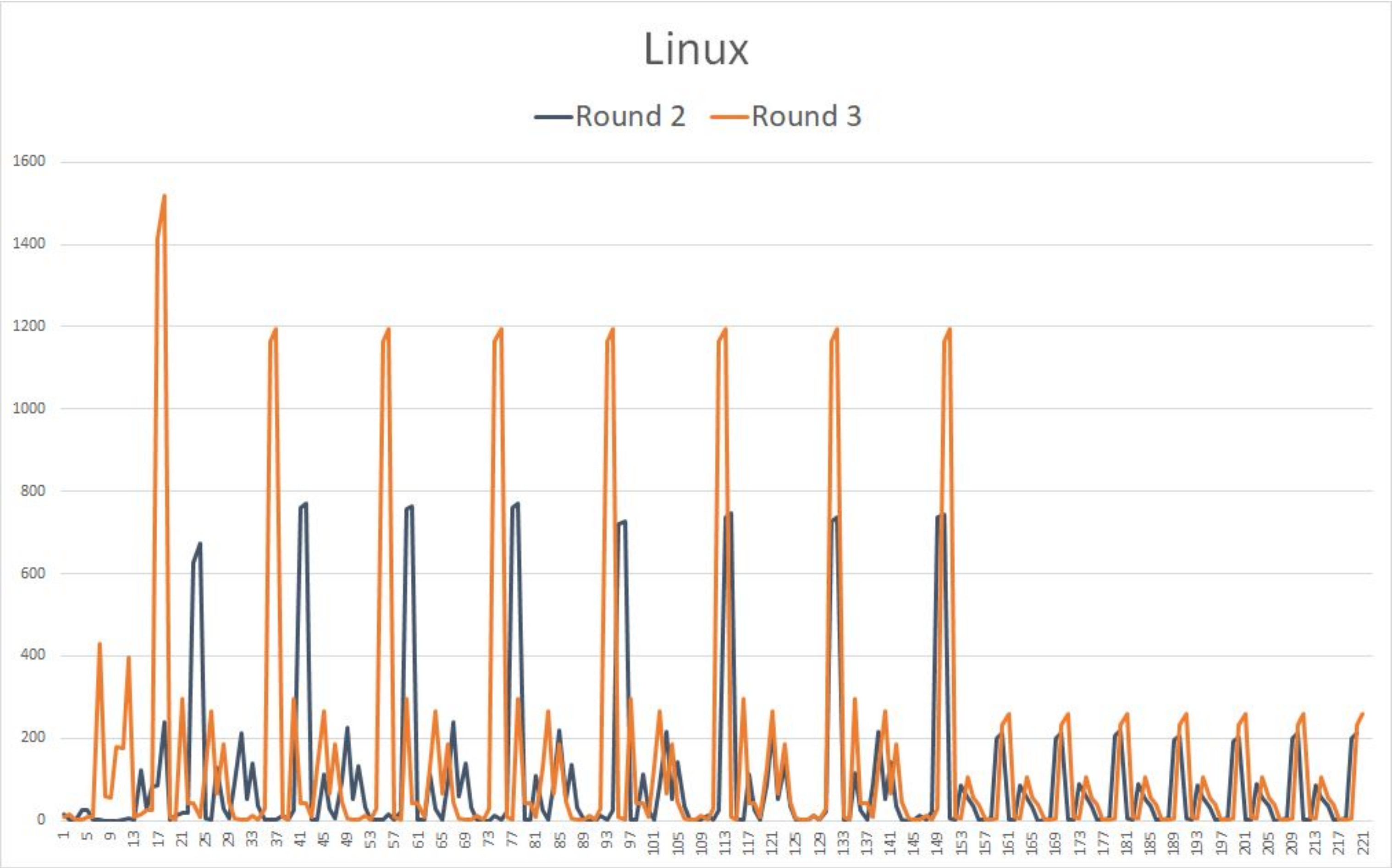

Linux
Round 2
Round 3
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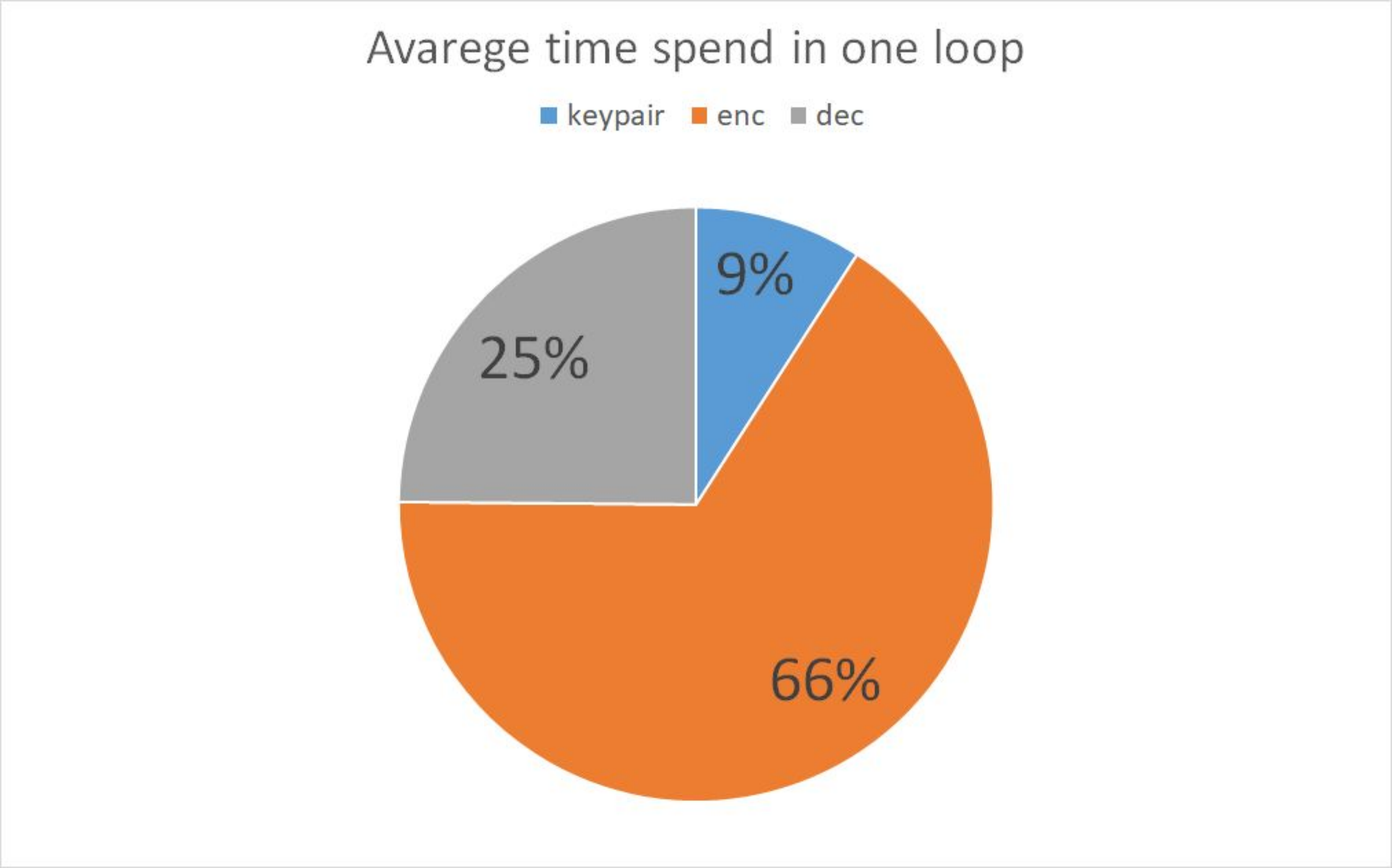


Avarege time spend in one loop
keypair
enc
dec
9%
25%
66%

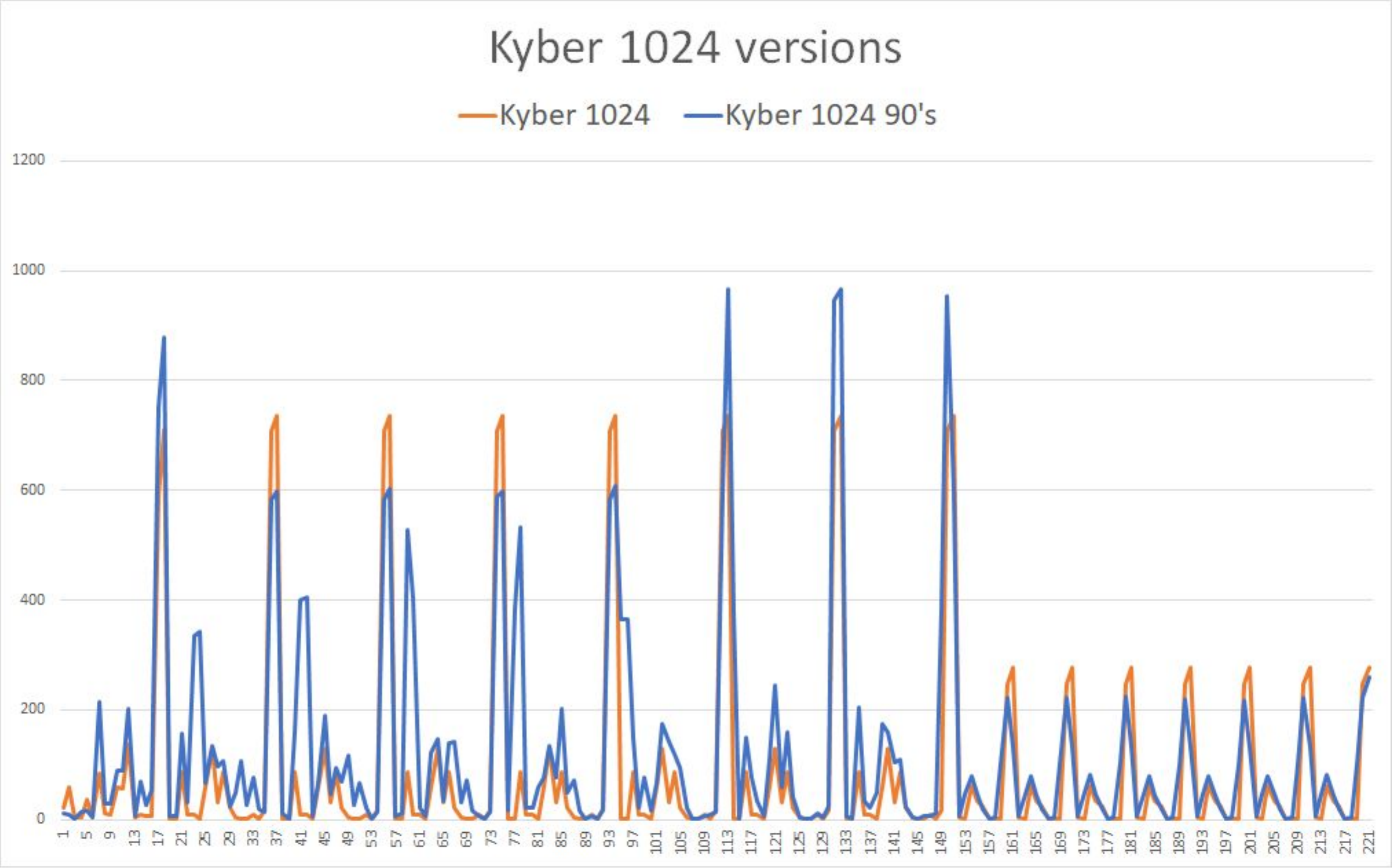
Kyber - Analysis Round 2 versus Round 3

- Analysis
  - Average execution time for Linux was increased
  - Average execution time for Android was reduced
  - Top values were kept

- Conclusion
  - Kyber was optimized for ARM architecture in newest NIST submission

Searching for code improvements

- Look for multiplication and division operations that could be replaced by bit shifting
    - Not found an effective change
- Use 90s variant to find out improvements
    - “The 90s variant of Kyber uses symmetric primitives that are standardized by NIST and accelerated in hardware on a large variety of platforms.” (Kyber, 2020)
    - For Galaxy S20 was not effective (see next slide), it increased the average execution time in 41.28%
        - Worst times for key pair generation and encryption
        - Better times for decryption



Kyber 1024 versions
Kyber 1024
Kyber 1024 90's
1200
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