|  |  |
| --- | --- |
| **Group** 8 | **Death Star Image Exfiltration** |
| **Major:** | **Team members:** |
| EE | Nicholas Michael |
| CEG | Mason McDaniel |
| IT/Cyber | Chase Ennis |
| IT/Cyber  CS | Cade Wrinkle  Michael Mowad |

**HW/SW Design Trade**

**Wireless Transceiver Development Board Comparison**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Solution** | **Rated Data Throughput** | **Rated Transmission Distance** | **Cost** | **Native Encryption Support** | **Hardware Interface** |
| NRF24L01 | 250Kbps / 1Mbps / 2Mbps [2] | 100 meters [2] | $1.39 [1] | None [2] | SPI [A] |
| Adafruit Feather nRF52840 Express | 250Kbps / 1Mbps / 2Mbps [4] | 100 meters  [4] | $24.95[4] | None [4] | SPI, UART, I2C, USB peripheral [4] |
| NRF52840-DONGLE | 1Mbps / 2Mbps [5] | Unknown | $10.00 [6] | AES-128 Accelerator [5] | USB [7] |
| SparkFun Pro nRF52840 Mini | 1Mbps / 2Mbps [8] | 300 meters / 100 meters [8] | $32.50 [9] | AES-128 [8] | SPI, UART, I2C, USB peripheral [8] |
| Nordic Thingy:91 | 250Kbps / 1Mbps / 2Mbps [10] | Unknown | $126.25 [11] | AES-128 [10] | SPI, UART, I2C, USB peripheral [10] |

The NRF52840-DONGLE is preferred due to its low cost and USB interface, which lends itself to interface both with the Raspberry Pi and the Rebel server. The Adafruit Feather Express and SparkFun Pro mini are of secondary preference due to their intermediate cost; they do have the benefit of providing a rated transmission distance. The Nordic Thingy:91 is not preferred due to its high unit cost. The NRF24L01 has a favorable unit cost, but it may potentially require more care to implement due to its lack of a USB interface.

Wireless Transmission Sources:

[1] "Makerfire Arduino NRF24L01 Wireless Transceiver Module," Amazon, [Online]. Available: <https://www.amazon.com/Makerfire-Arduino-NRF24L01-Wireless-Transceiver/dp/B00O9O868G>. Accessed: October 11, 2024.

[2] “nRF24L01+ Preliminary Product Specification," SparkFun, Jan. 2020. [Online]. Available: <https://www.sparkfun.com/datasheets/Components/SMD/nRF24L01Pluss_Preliminary_Product_Specification_v1_0.pdf>. Accessed: October 11, 2024.

[3] "NRF24L01 Tutorial: Arduino Wireless Communication," Instructables. [Online]. Available: <https://www.instructables.com/NRF24L01-Tutorial-Arduino-Wireless-Communication/>. Accessed: October 11, 2024.

[4] "Adafruit NRF24L01+ 2.4GHz RF Transceiver - 2Mbps, 100mW" Digi-Key.[Online]. Available: <https://www.digikey.com/en/products/detail/adafruit-industries-llc/4062/9843410?s=N4IgjCBcoLQBxVAYygMwIYBsDOBTANCAPZQDa4ArAEwIC6AvvYVWSACwAMAbCw0A>. Accessed: October 11, 2024.

[5] *“*nRF52840*”* Mouser. [Online]. Available: <https://www.mouser.com/datasheet/2/297/nrf52840_soc_v3_0-2942478.pdf>.Accessed: October 14, 2024.

[6] “NRF52840-DONGLE.” Digikey. [Online]. Available: <https://www.digikey.com/short/72z130hw>. Accessed: October 21, 2024.

[7] “nRF52840 Dongle.” Nordic Semiconductor. [Online]. Available: <https://docs.nordicsemi.com/bundle/ug_nrf52840_dongle/page/UG/nrf52840_Dongle/intro.html>. Accessed: October 21, 2024.

[8] “Approval Sheet” Raytac Corporation. [Online]. Available: <https://cdn.sparkfun.com/assets/learn_tutorials/8/2/0/Raytac_MDBT50Q.pdf.> Accessed: October 21, 2024.

[9] “SparkFun Pro nRF52840 Mini - Bluetooth Development Board” SparkFun. [Online]. Available: <https://www.sparkfun.com/products/15025>. Accessed: October 21, 2024.

[10] “Nordic Thingy:91” Nordic Semiconductors. [Online]. Available: <https://www.nordicsemi.com/-/media/Software-and-other-downloads/Product-Briefs/Nordic-Thingy-91-PB-v2.1.pdf>. Accessed: October 18, 2024.

[11] “NRF6943“ Digikey. [Online]. Available: <https://www.digikey.com/en/products/detail/nordic-semiconductor-asa/NRF6943/10291811>. Accessed: October 18, 2024.

**Image Recognition**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ***Option [Rents]*** | **Memory Requirements**  **[Opt]** | ***Speed & Efficiency***  ***[Opt]*** | **Ease of Integration**  **[Opt]** | **Compatibility**  **[60]** | **Cost ($)**  **[Opt]** |
| *OpenCV* | 256 MB RAM minimum [14] | Fast [1] | Easy[1] | Cross-Platform  [2] | Free [7] |
| TensorFlow | 4 GB RAM [3] | Average [3] | Average [3] | Cross-Platform  [8] | Free [8] |
| YOLO | 388 MB RAM [15] | Fast [4] | Average [4] | Cross-Platform  [9] | Free [9] |
| Amazon Rekognition | Cloud Based, Minimal System Requirements[5] | Average [5] | Easy[5] | Cloud-Based  [5] | ~ $0.0010 per image [6] |
| PyTorch | 4 – 8 GB RAM[14] | Slow [10] | Average [11] | Cross-Platform [11] | Free [11] |

Image Recognition Design Explanation:

This table compares several different image recognition tools based on several factors such as memory requirements, speed, ease of integration, compatibility, and cost. Tools like OpenCV and YOLO are considered “fast” because they can process images in real-time or near real-time. This is critical for tasks like quick object detection using as few resources as possible. TensorFlow and PyTorch are classified as “average” due to the fact they are more complex but may take longer to compute the data involved and process the image. Ease of integration defines how documented and how many API’s and prebuilt functions (such as programming languages or data libraries) are available. Tools like OpenCV and Amazon Rekognition are well documented API’s, prebuilt functions, and support. Tools like YOLO and PyTorch may need more knowledge and (or) setup. These classifications are based off how efficiently the tools handle these tasks and how quickly they can be set up and implemented with as few issues as possible.

Image Recognition Sources:

[1] OpenCV, "Introduction and Overview," [Online]. Available: <https://docs.opencv.org/4.x/>. [Accessed: 14-Oct-2024].

[2] OpenCV, "Platforms," [Online]. Available: <https://opencv.org/platforms/>. [Accessed: 14-Oct-2024].

[3] StackOverflow, "What are the minimum system requirements for executing a simple project in TensorFlow?" [Online]. Available: <https://stackoverflow.com/questions/43985250/what-are-the-minimum-system-requirements-for-executing-a-simple-project-in-tenso>. [Accessed: 15-Oct-2024].

[4] P. Reddie, "YOLO: Real-Time Object Detection Explained," [Online]. Available: <https://pjreddie.com/darknet/yolo/>. [Accessed: 15-Oct-2024].

[5] AWS, "AWS Rekognition Overview," [Online]. Available: <https://aws.amazon.com/rekognition/>. [Accessed: 14-Oct-2024].

[6] AWS, "AWS Rekognition Pricing Details," [Online]. Available: <https://aws.amazon.com/rekognition/pricing/>. [Accessed: 14-Oct-2024].

[7] OpenCV, "License," [Online]. Available: <https://opencv.org/license/>. [Accessed: 14-Oct-2024].

[8] TensorFlow, "Install Guide," [Online]. Available: <https://www.tensorflow.org/install>. [Accessed: 16-Oct-2024].

[9] A. B. Alexey, "YOLO on Darknet GitHub," [Online]. Available: <https://github.com/AlexeyAB/darknet>. [Accessed: 15-Oct-2024].

[10] PyTorch, "PyTorch License," [Online]. Available: <https://pytorch.org/get-started/locally/>. [Accessed: 14-Oct-2024].

[11] PyTorch, "PyTorch Documentation," [Online]. Available: <https://pytorch.org/docs/stable/index.html>. [Accessed: 15-Oct-2024].

[12] OpenCV, "Laptop minimum system requirement for OpenCV," [Online]. Available: <https://answers.opencv.org/question/179923/laptop-minimum-system-requirement-for-opencv/>. [Accessed: 16-Oct-2024].  
[13] Raspberry Pi Forum, "Laptop minimum system requirement for OpenCV," [Online]. Available: <https://forums.raspberrypi.com/viewtopic.php?t=259562>. [Accessed: 16-Oct-2024].

[14] PyTorch Forum, "How to know the exact GPU memory requirement for a certain model?" [Online]. Available: <https://discuss.pytorch.org/t/how-to-know-the-exact-gpu-memory-requirement-for-a-certain-model/125466>. [Accessed: 16-Oct-2024].

**Encryption**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ***Option [Requirements]*** | **Compatible on Raspberry PI [80]** | **Tutorials Available [Opt]** | **License**  **[Opt]** | **Overhead**  **[Opt]** |
| **OpenSSL** | Yes [1] | [2], [3], [11] | Apache 2.0 [7] | 10 bits [Team Experiment] |
| **LibgCrypt** | Yes [4] | [4], [12] | LGPLv2.1+ [8] | 26 bits [Team Experiment] |
| **PyCrypto** | Yes [5] | [5], [13] | Partially Public Domain, Partially Under BSD 2-Clause license [9] | 26 bits [Team Experiment] |
| **GnuPG** | Yes [6] | [6], [14] | GPL [10] | 71 bits [Team Experiment] |
| **NRF52840-DONGLE** | Yes [16] | [15] | N/A | N/A |

We examined the different libraries that we can run the AES-128 encryption algorithm on. Since the Raspberry Pi runs the OS Raspbian, which is a Linux distribution. Ubuntu is another distribution of Linux. All the algorithms are compatible with Ubuntu; thus, it will work with Raspbian. There were tutorials for everything, although OpenSSL by far has the most available. All the libraries have a valid license. Since speed and efficiency is everything with this project, the overhead was a critical factor to consider after encryption (see our experiment below). OpenSSL by far has the smallest difference in overhead size. GnuPG had the largest overhead size. Both LibgCrypt and PyCrypto had the same overhead size after encryption. We also examined the hardware equipment for the NRF52840-Dongle, and the onboard encryption was unclear, and the tutorials were lacking. Therefore, from this point forward, implementing the OpenSSL library is of best interest.

Team Experiment

A screenshot of a computer

Description automatically generated

Encryption Sources:

[1] S. Sharma, "How to install OpenSSL on Ubuntu Server," *Learn Ubuntu*, Nov. 28, 2022. [Online]. Available: https://learnubuntu.com/install-openssl/. [Accessed: Oct. 21, 2024].

[2] R. Van de Paar, "Raspberry Pi: How to install OpenSSL 1.0.2 on Raspberry Pi3? (2 Solutions!!)," *YouTube,* Dec. 19, 2020. [Online]. Available: https://www.youtube.com/watch?v=WkXeHAwaLHg. [Accessed: Oct. 21, 2024].

[3] A. Khan, "How to Update OpenSSL on Raspberry Pi," *Linux Hint*, 2022. [Online]. Available: https://linuxhint.com/update-open-ssl-raspberry-pi/. [Accessed: Oct. 21, 2024].

[4] "How to Install the Libcrypto Library on Ubuntu," *CommandFound*, [Online]. Available: https://commandfound.com/post/libcryptolib-not-found-ubuntu/. [Accessed: Oct. 21, 2024].

[5] "pycrypto 2.6.1," *AWS*, Oct. 17, 2013. [Online]. Available: https://pypi.org/project/pycrypto/. [Accessed: Oct. 21, 2024].

[6] "How To Install gnupg on Ubuntu 20.04," *Installati.one*, [Online]. Available: https://installati.one/install-gnupg-ubuntu-20-04/. [Accessed: Oct. 21, 2024].

[7] "OpenSSL License," OpenSSL Wiki, Jul. 22, 2020. [Online]. Available: https://wiki.openssl.org/index.php/License. [Accessed: Oct. 21, 2024].

[8] "Libgcrypt," *GnuPG*, [Online]. Available: https://www.gnupg.org/software/libgcrypt/index.html. [Accessed: Oct. 21, 2024].

[9] "PyCryptodome License," *PyCryptodome*, [Online]. Available: https://pycryptodome.readthedocs.io/en/latest/src/license.html. [Accessed: Oct. 21, 2024].

[10] "GNU General Public License," *GNU Operating System*, [Online]. Available: https://www.gnu.org/licenses/gpl-3.0.html. [Accessed: Oct. 21, 2024].

[11] "Encrypt & Decrypt Files With Password Using OpenSSL," *ShellHacks*, [Online]. Available: https://www.shellhacks.com/encrypt-decrypt-file-password-openssl/. [Accessed: Oct. 21, 2024].

[12] "The Libgcrypt Library," *GnuPG*, Apr. 6, 2023. [Online]. Available: https://www.gnupg.org/documentation/manuals/gcrypt/. [Accessed: Oct. 21, 2024].

[13] D. Damian, "Implementing AES-256 Encryption and Decryption with PyCrypto in Python 3," *DNM*, Oct. 16, 2023. [Online]. Available: https://dnmtechs.com/implementing-aes-256-encryption-and-decryption-with-pycrypto-in-python-3/. [Accessed: Oct. 21, 2024].

[14] "Encrypting and decrypting documents," *The GNU Privacy Handbook*, [Online]. Available: https://www.gnupg.org/gph/en/manual/x110.html. [Accessed: Oct. 21, 2024].

[15] "IEEE CCM — AES CCM mode encryption." *Nordic Semiconductor ASA*,

Oct. 1, 2024. [Online]. Available: <https://docs.nordicsemi.com/bundle/ps_nrf52840/page/ccm.html> [Accessed: Oct. 25, 2024].

[16] "Adafruit NRF24L01+ 2.4GHz RF Transceiver - 2Mbps, 100mW" *Digi-Key*. [Online]. Available: <https://www.digikey.com/en/products/detail/adafruit-industries-llc/4062/9843410?s=N4IgjCBcoLQBxVAYygMwIYBsDOBTANCAPZQDa4ArAEwIC6AvvYVWSACwAMAbCw0A>. Accessed: October 11, 2024.