Receiving data through light with low-end smartphones

By: Shaan Hossain (S.Hossain@student.tudelft.nl)

Supervisors: Prof. dr. K.G. Langendoen, M.A. Zuñiga Zamalloa

Background

2003 - first experiments with visible light communication (VLC) with an camera [1]

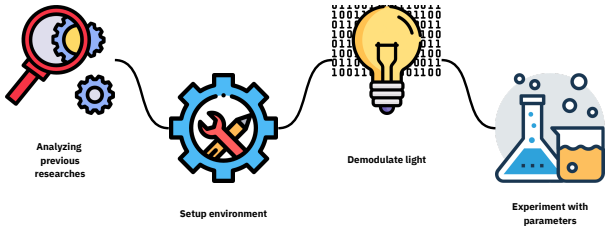
2012 - spectrum crunch becomes worrisome [2]

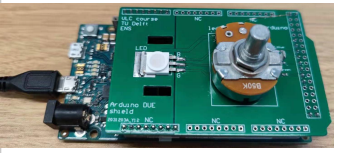
2017 - first real-life applications with visible light communication [3]

Research Question

How can we demodulate an optical signal with low-end smartphones that are limited computational resources affecting latency and throughput?

Methodology



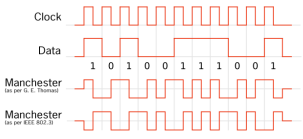


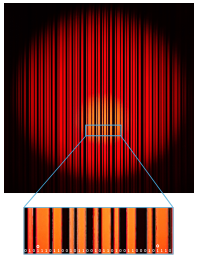
Transmitter

- Arduino DUE with LED
- Modulate data by flickering the LED at a high frequency

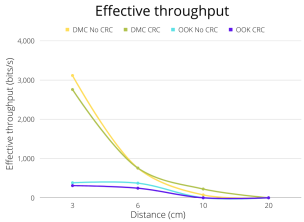
Receiver

- 240fps smartphone camera + Android app
- Use rolling shutter effect for demodulating
- Experiment with different demodulation techniques:
  - On-Off Keying (OOK)
  - Differential Manchester Code (DMC)
  - Cyclic Redundancy Check (CRC)
  - At different distances



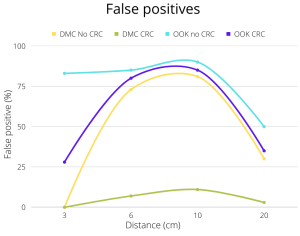


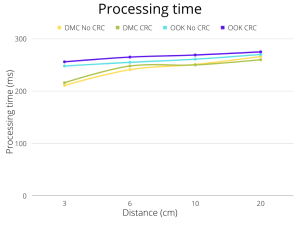
Results



- DMC outperforms OOK by 8x
- CRC makes no significant difference
- OOK does not work well in current setup at any range
- Only close-range is consistent in data transfer

- DMC outperforms OOK by 20x
- CRC does have an positive impact on close and long-ranges
- At long range the header is undetectable, which results in no message at all





- Distance is not significant for processing time
- OOK is expected to be much faster but still is actually slower than DMC
- Extra computation caused by CRC is minimal

Conclusion

- DMC is significantly better than OOK
- Algorithms used in this setup is only effective at close-range
- Higher throughput is desired over longer messages

Future work

- Experiment with different clock speeds and message lengths
- Use different low-end smartphones
- Change the detection and tracking algorithm
- Create an optimal Pareto front

References:
[1] T. Komine and M. Nakagawa, "Fundamental analysis for visible-light communication system using LED lights," in IEEE Transactions on Consumer Electronics, vol. 50, no. 1, pp. 100-107, Feb. 2004, doi: 10.1109/TCE.2004.1277847.
[2] M. Kavehrad, "Optical wireless applications: a solution to ease the wireless airwaves spectrum crunch," SPIE Proceedings, Jan. 2013, doi: 10.1117/12.2005110.
[3] A. Sarkar, A. Nath, and S. Agarwal, "Li-Fi: Light Fidelity-the transmission of data through light," International Journal of Science and Research (IJSR), vol. 6, no. 7, pp. 376–381, 2017.
[4] "Manchester code," Wikipedia, Jun. 12, 2021. en.wikipedia.org/wiki/Manchester_code

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