Evaluation of the Cell Allocation Mechanism in 6TiSCH Minimal Scheduling Function for Wireless Sensor Networks - Midterm

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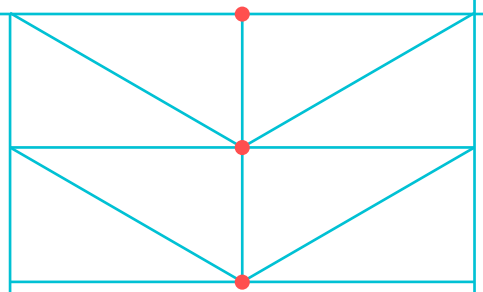

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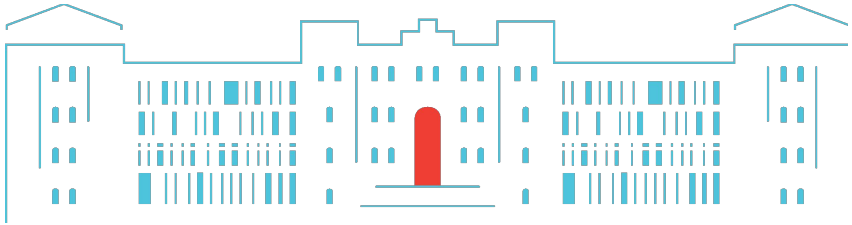

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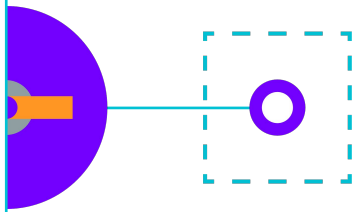
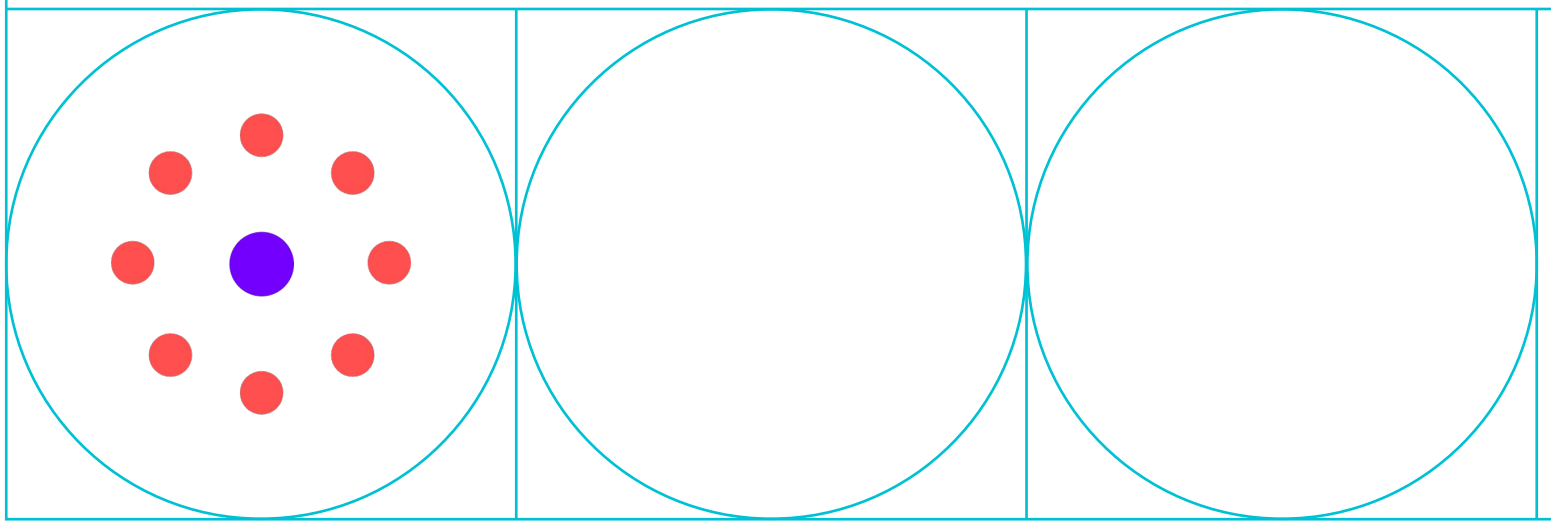
Supervisor: Yevhenii Shudrenko
First Examiner: Prof. Timm-Giel

Agenda:

1. Introduction
2. Current state
3. Problems
4. Schedule



1. Introduction



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1. Introduction – 6TiSCH

- Enables IPv6 for LLN networks using IEEE 802.15.4
- 6TiSCH stands for IPv6 over TSCH
- Convergence of Operational Technology (OT) and Information Technology (IT)[8]
- Using 6LoWPAN standard for e.g. header compression and neighbour discovery

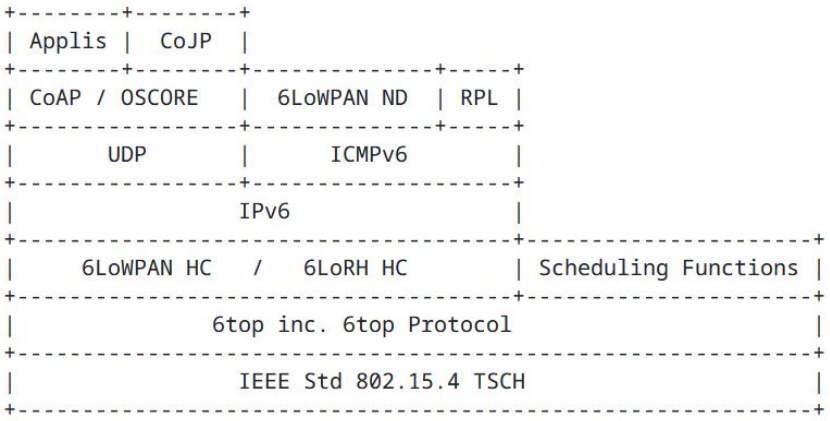


Figure 2. Protocol stack of 6TiSCH [1]

1. Introduction – 6TiSCH

- TSCH used as MAC protocol
  - Mix of TDM/FDM creating a matrix of cells for transmission
  - 6top Protocol (6P) used as communication [3]
- Scheduling function (SF) handles schedule

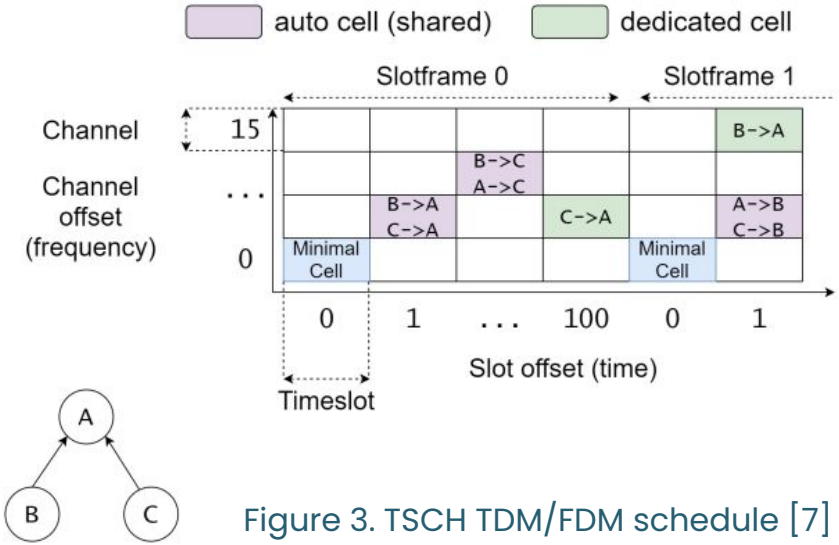
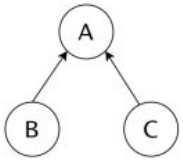


Figure 3. TSCH TDM/FDM schedule [7]

1. Introduction – Scheduling Function

- The scheduling functions tasks for a node are: [1]
  - When and how many to cells add/delete
  - Which cells to include in CellList of the 6P ADD request
- The only scheduling function that has a official RFC by the IETF is the Minimal Scheduling function



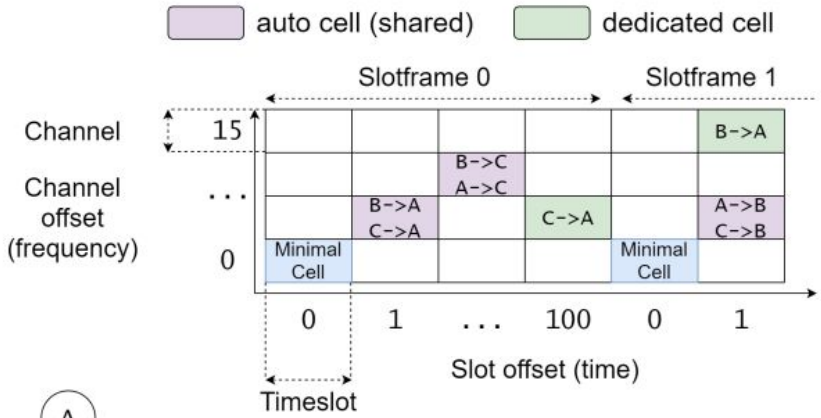


Figure 3. TSCH TDM/FDM schedule [7]

1. Introduction - Minimal Scheduling Function (MSF)

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- Has mechanisms to decide when to add/delete cells
- CellList is chosen randomly and uniformly
- Example: Relocation of a cell

$PDR_{cellmax} - PDR_i > RELOCATE\_PDRTHRES$

⇒ If true MSF will relocate the cell

PDR = Packet delivery ratio

Name	RECOMMENDED value
SLOTFRAME_LENGTH	101 slots
NUM_CH_OFFSET	16
MAX_NUM_CELLS	100
LIM_NUMCELLSUSED_HIGH	75
LIM_NUMCELLSUSED_LOW	25
MAX_NUMTX	256
HOUSEKEEPINGCOLLISION_PERIOD	1 min
RELOCATE_PDRTHRES	50 %
QUARANTINE_DURATION	5 min
WAIT_DURATION_MIN	30 s
WAIT_DURATION_MAX	60 s

Figure 4. MSF recommended values [4]

1. Introduction - Cell allocation mechanisms

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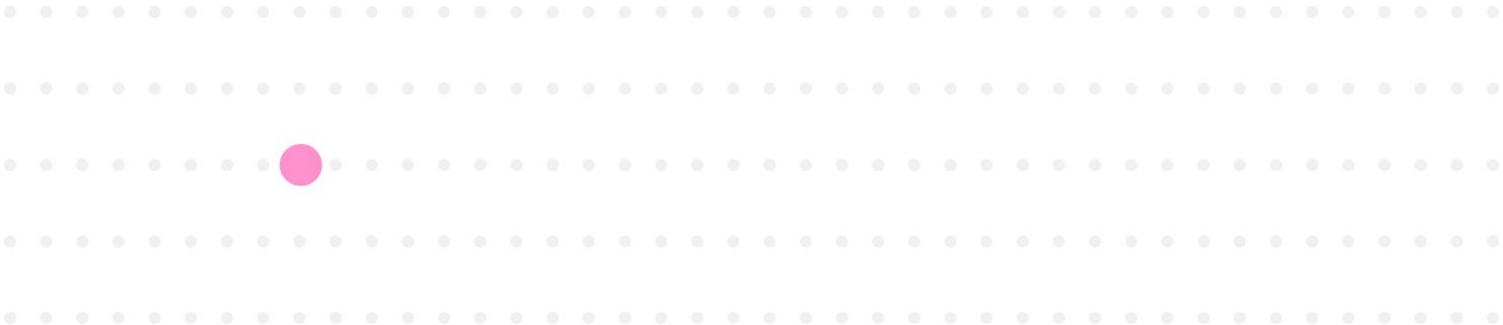
- Different cell allocation mechanisms to evaluate:
  - Random uniform selection of free cells (default)
  - Keeping a list of candidates in which the node listens and if traffic is detected then it will be exchanged with another cell
    - Stated as possibility in RFC for MSF [4]

2. Current state



2. Current state - Thesis

Section of Thesis	Progress
Introduction	95%
Background	95%
Related work	95%
Analytical model	50%
Experimental validation	30%
Conclusion	0%

2. Current state - Analytical model

$$T_s = T_a + T_r \min(\lfloor E_\Sigma[O] \rfloor, 1)$$

2. Current state - Analytical model

$$T_a = \sum_{i=1}^{\mu_{\max}-1} \left(\frac{M}{\mu_i} + \frac{1}{\mu_i + 1} + 0.5 \right), \quad \mu_i = i$$

$$T_r = 2HOUSEKEEPINGCOLLISION\_PERIOD + \frac{1}{\mu_i + 1} + 0.5$$

2. Current state - Analytical model

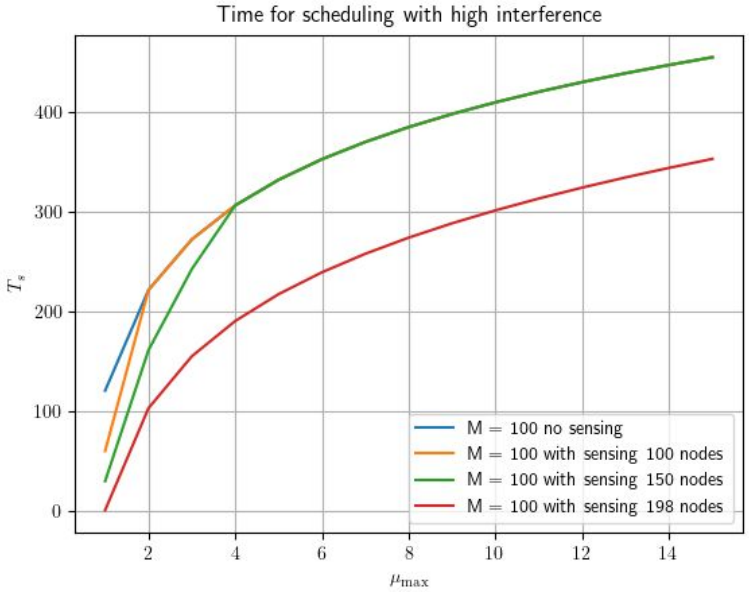
$$T_s = T_a + T_r \min(\lfloor E_\Sigma[O] \rfloor, 1)$$

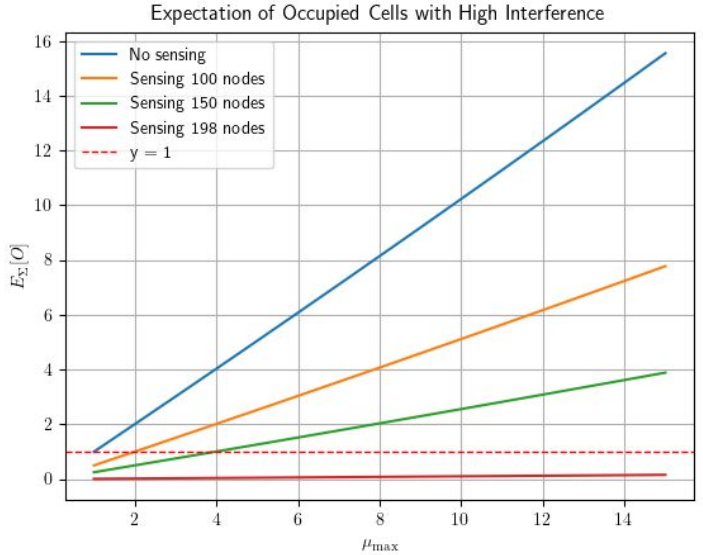
$$E_\Sigma[O] = \sum_{i=1}^{\mu_{\max}} \frac{1}{1 - p_{nov}(\mu_i)}$$

$$p_{nov}(\mu_i) = 1 - \frac{n\mu_i + N}{X - \mu_{i-1}}$$

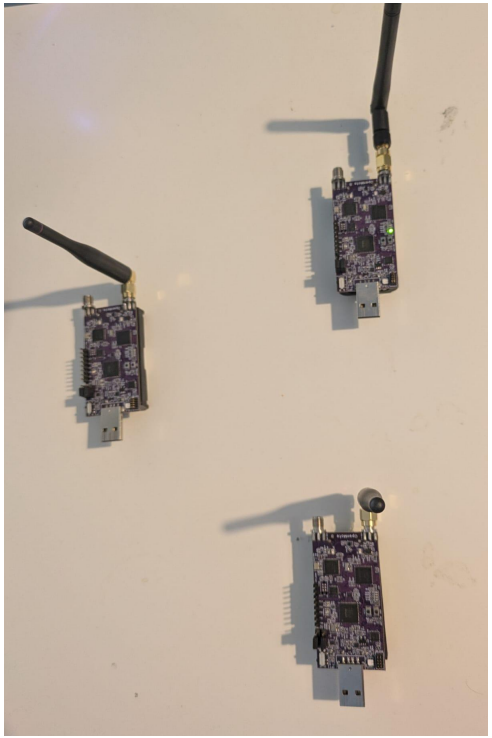
$$p^*_{nov}(\mu_i) = 1 - \frac{n\mu_i - n_s}{X - \mu_{i-1} - n_s}$$

2. Current state - Analytical model





2. Current state - Experimental setup



3 Openmote-B nodes:
- Parent (TSCH-coordinator, RPL-root)
- Network emulator
- Child

Additional implementation added in Contiki-NG code:
- Setting up of autonomous cells
- Relocation mechanism
- Interferer mechanism of broadcasting
- Sensing approach

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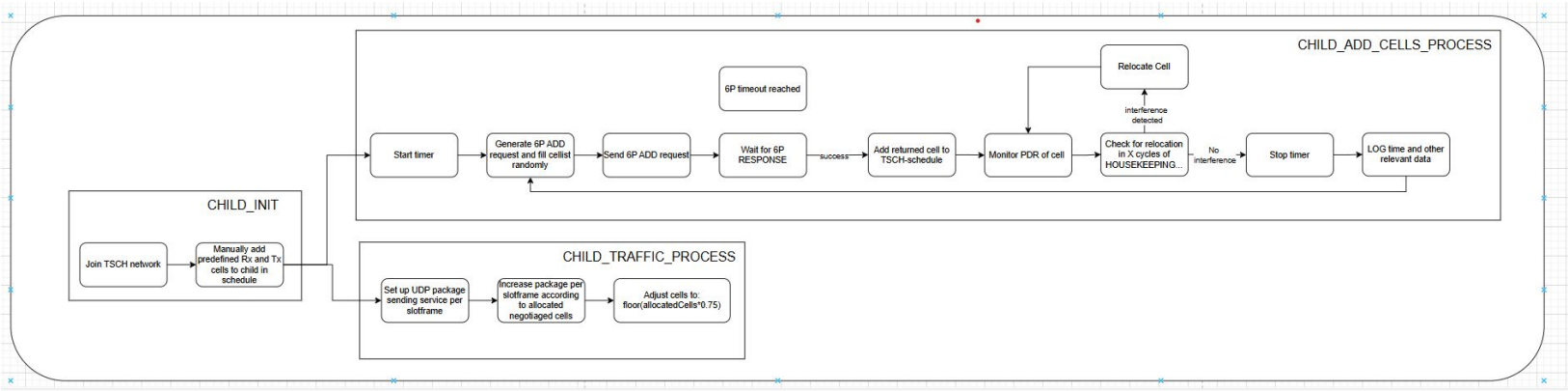

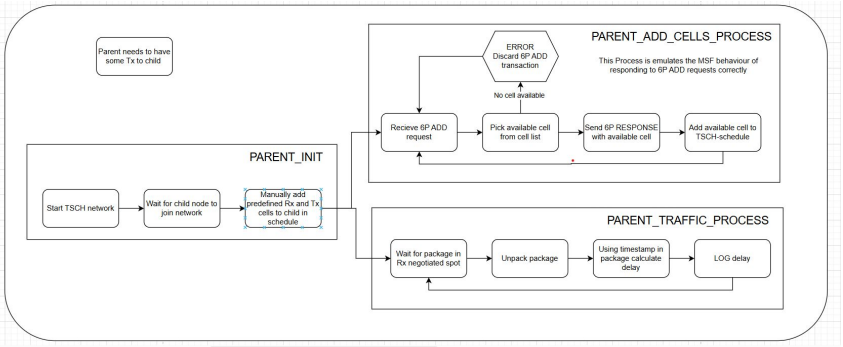

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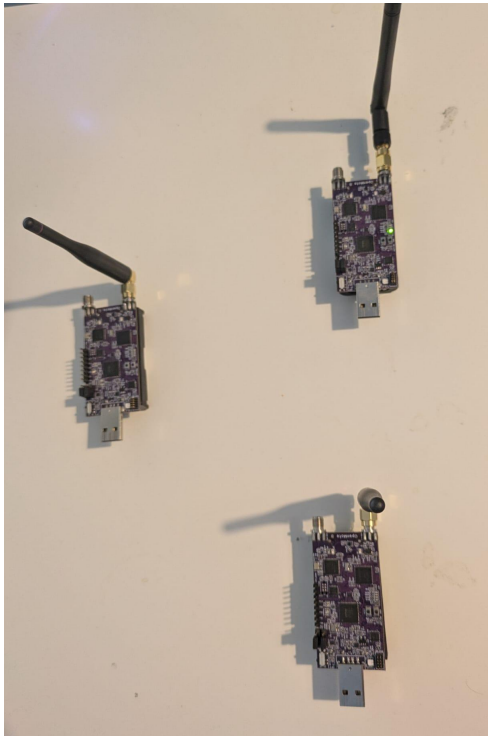

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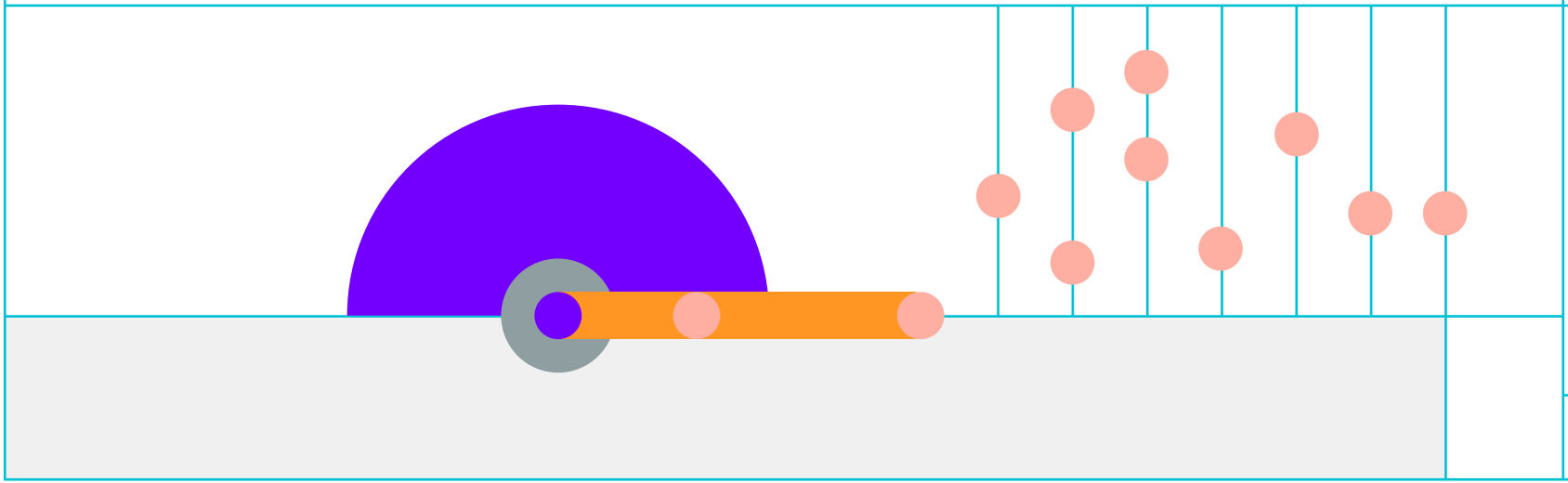
3. Challenges



3. Challenges

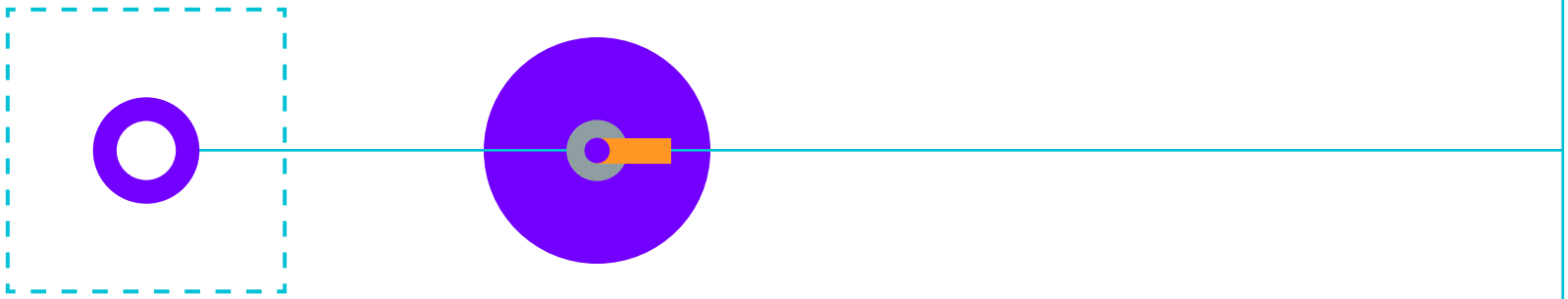
Analytical:

- Difficulties of unifying a general and abstract model with detailed experimental setup
  - Especially for sensing allocation approach

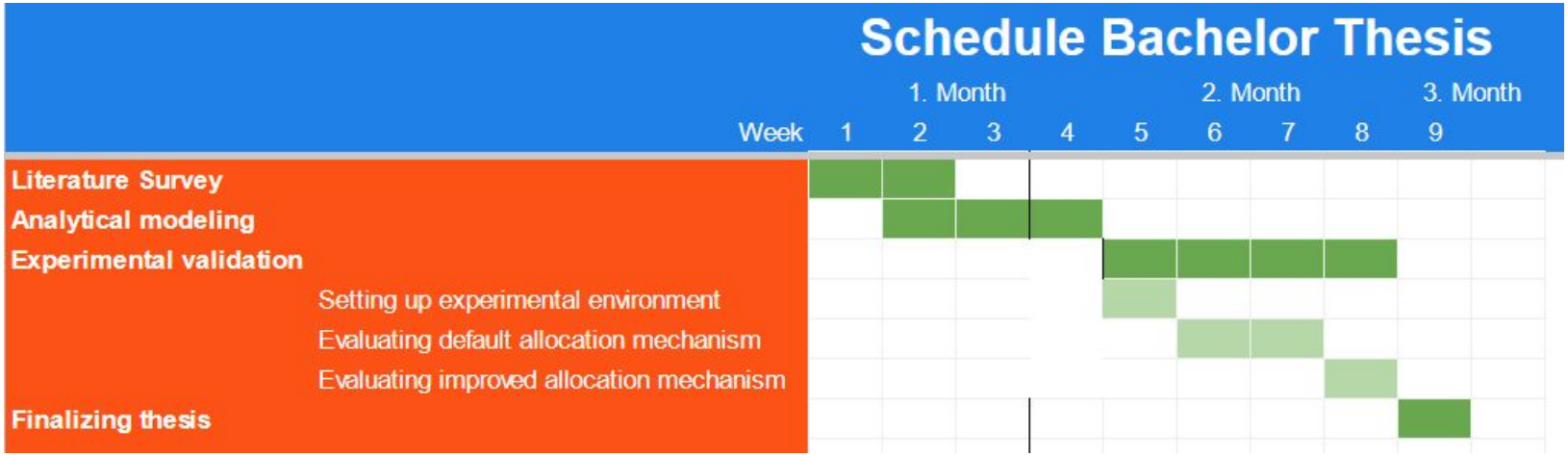
Experimental:

- Boards get bricked and can only be fixed with debugger
- At times unpredictable behaviour due to parallel processes

4. Schedule



4. Schedule



References

[1] Pascal Thubert . ‘An Architecture for IPv6 over the Time-Slotted Channel Hopping Mode of IEEE 802.15.4 (6TiSCH)’ . RFC 9030 . May 2021 . url: https://datatracker.ietf.org/doc/html/rfc9030.

[2] https://pixabay.com/images/search/iot%20network/ . Pixabay . last visited 27.11.2024

[3]Qin Wang , Xavier Vilajosana , Thomas Watteyne . 6TiSCH Operation Sublayer (6top) Protocol (6P) . RFC 8480 . November 2018 . https://datatracker.ietf.org/doc/rfc8480/ .

[4] T. Chang, Ed., M. Vučinić, Inria, X. Vilajosana, . ‘6TiSCH Minimal Scheduling Function (MSF)’ . RFC 9033. May 2021. doi: 10.17487/RFC9033. url: https://datatracker.ietf.org/doc/rfc9033/ .

[5] David Hauweele, Remous-Aris Koutsiamanis, Bruno Quoitin et al. ‘Pushing 6TiSCH Minimal Scheduling Function (MSF) to the Limits’. In: 2020 IEEE Symposium on Computers and Communications (ISCC). 2020, pp. 1–7. doi: 10.1109/ISCC50000.2020.9219692.

[6] David Hauweele, Remous-Aris Koutsiamanis, Bruno Quoitin et al. ‘Thorough Performance Evaluation & Analysis of the 6TiSCH Minimal Scheduling Function (MSF)’. In: Journal of Signal Processing Systems 93 (6 June 2021). doi: 10.1007/S11265-021-01668-w.

[7] Lukas Borutta. 'Evaluation of the Minimal Scheduling Function for 6TiSCH-based Wireless Sensor Networks' . (16 September 2021)

[8] Pascal Thubert . ‘IPv6 over the TSCH mode of IEEE 802.15.4e’ . https://datatracker.ietf.org/wg/6tisch/about/ . last visited 15.12.2024.

Thank you!

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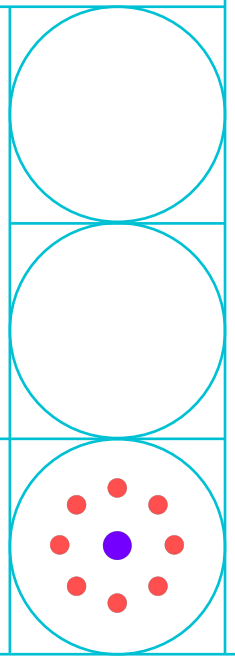

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