



Towards standardized 6G connectivity for ambient-powered energy neutral IoT devices

## Deliverable D5.1

DELIVERABLE NAME



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**Abstract**

This deliverable . . . .

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**Disclaimer**

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## Executive Summary

This document, reporting on D5.1, ... AMBIENT-6G.

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# Glossary

**eCDF** empirical cumulative distribution function.

**RSS** received signal strength.

# Chapter 1

## Examples for a coherent document

**Add content:** Revision done

*Responsible partner:* KUL

- Add yourself to the contributor list in `input/contributors.tex`
- Make use of the **glossaries** package to conveniently expand abbreviations in the correct manner. The abbreviations are located in `abbr.tex`.
- Use distinct and descriptive labels to reference figures/tables/...
- **British English** is preferred for EU projects.
- Make use of *tikzplotlib* (Python), *matlab2tikz* (Matlab) or use plain old CSV to transform eps/png/pdf figures to **tikz** figures which gives us more control over the aesthetics of the figures (coherent coloring scheme, font size, font family, size,...)
- Try to make use of pre-defined commands to **format math notations**. These are listed in the `sty/math_notations.tex` file. Example:

```
\usepackage{xifthen}
\newcommand{\prob}[1][ ]{%requires xifthen package%
\ifthenelse{\isempty{#1}}{%
{\ensuremath{P}}}%
{\ensuremath{P\left\{#1\right\}}}%
}
\newcommand{\vect}[1]{\boldsymbol{\mathrm{#1}}}
\newcommand{\mat}[1]{\boldsymbol{\mathrm{#1}}}
\newcommand{\MSE}{\mathrm{MSE}}
\newcommand{\tr}{\mathrm{tr}}
\newcommand{\moddef}{\mathrm{mod}}
\newcommand{\diag}{\mathrm{diag}}
\newcommand{\vecop}{\text{vec}}
\newcommand{\CP}{L}
\newcommand{\hddots}{\mathrm{hdots}}
\newcommand*{\inC}[1]{\in\mathbb{C}^{#1}}
\newcommand{\norm}[1]{\left\lVert#1\right\rVert}
```

```
\newcommand{\abs}[1]{\left\lvert#1\right\rvert}
\newcommand{\expt}[1]{\mathbb{E} \left\{#1\right\}}
\newcommand{\cn}[2]{\ensuremath{\sim\mathcal{C}\mathcal{N}\left(#1,#2\right)}}
```

- You can use @KUL to address a question to a certain partner. Please use your own comment command, so the referenced partner, knows who asked the question, made the remark, e.g., [NXP : has a question, @TUG can you elaborate?] These definitions are located in the 'sty/defs.tex' file.

## 1.1 Using Colors

### 1.1.1 Color theme of the project

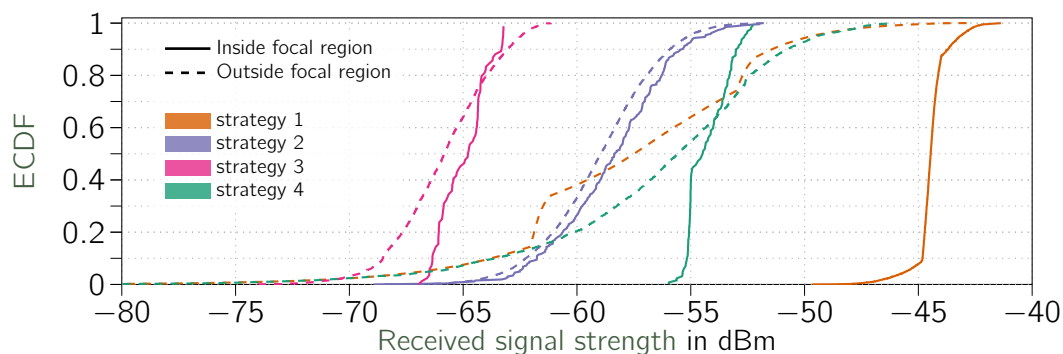


### 1.1.2 Color theme of the graphs

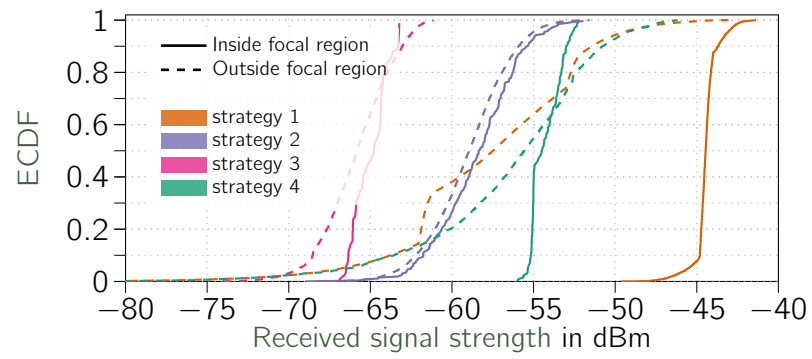


## 1.2 Using Tikz

Make use of tikz whenever possible. This allows us to have coherent coloring schemes and correct scaling and naming conventions. Examples:







## 1.3 Using abbreviations

## Chapter 2

## Conclusion

# References

- [1] G. Callebaut, G. Leenders, J. Van Mulders, G. Ottoy, L. De Strycker, and L. Van der Perre, "The Art of Designing Remote IoT Devices—Technologies and Strategies for a Long Battery Life," *Sensors*, vol. 21, no. 3, Jan. 2021, ISSN: 1424-8220. DOI: 10.3390/s21030913. [Online]. Available: <https://www.mdpi.com/1424-8220/21/3/913>.
- [2] G. Callebaut, J. Van Mulders, G. Ottoy, D. Delabie, B. Cox, N. Stevens, and L. Van der Perre, "Techtile – Open 6G R&D Testbed for Communication, Positioning, Sensing, WPT and Federated Learning," in *2022 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, Grenoble, France, 2022, pp. 417–422. DOI: 10.1109/EuCNC/6GSummit54941.2022.9815696.
- [3] G. Callebaut, J. Van Mulders, B. Cox, L. van der Perre, L. De Strycker, and F. Rottenberg, "How to Perform Distributed Precoding to Wirelessly Power Shelf Labels," English, in *2024 IEEE 25TH INTERNATIONAL WORKSHOP ON SIGNAL PROCESSING ADVANCES IN WIRELESS COMMUNICATIONS, SPAWC 2024*, ser. IEEE International Workshop on Signal Processing Advances in Wireless Communications, ITALY, Lucca, IEEE, 2024, pp. 526–530, ISBN: 979-8-3503-9319-4. DOI: 10.1109/SPAWC60668.2024.10693966.
- [4] G. Callebaut, L. Liu, T. Eriksson, L. Van der Perre, O. Edfors, and C. Fager, "6G Radio Testbeds: Requirements, Trends, and Approaches," *Ieee Microwave Magazine*, 2024, ISSN: 1527-3342.
- [5] G. Callebaut, M. sandra, C. nelson, T. wilding, D. Delabie, B. J.B. Deutschmann, W. Tärneberg, E. Fitzgerald, A. Johansson, and L. Van der Perre, "An Open Dataset Storage Standard for 6G Testbeds," in *Proceedings of 2023 IEEE Conference on Antenna Measurements and Applications (CAMA) (2023 IEEE CAMA)*, Genoa, Italy, 2023.
- [6] G. Callebaut, J. Van Mulders, G. Ottoy, and L. Van der Perre, "A Primer on Techtile: An R&D Testbed for Distributed Communication, Sensing and Positioning," in *2021 Symposium on Information Theory and Signal Processing in the Benelux*, Eindhoven, The Netherlands, May 2021.
- [7] J. Van Mulders, D. Delabie, C. Lecluyse, C. Buyle, G. Callebaut, L. Van der Perre, and L. De Strycker, "Wireless Power Transfer: Systems, Circuits, Standards, and Use Cases," *Sensors*, vol. 22, no. 15, Jul. 2022, ISSN: 1424-8220. DOI: 10.3390/s22155573.
- [8] J. van Mulders, B. Cox, B. Deutschmann, G. Callebaut, L. De Strycker, and L. van der Perre, "Keeping Energy-Neutral Devices Operational: a Coherent Massive Beamforming Approach," English, in *2024 IEEE 25TH INTERNATIONAL WORKSHOP ON SIGNAL PROCESSING ADVANCES IN WIRELESS COMMUNICATIONS, SPAWC 2024*, ser. IEEE International Workshop on Signal Processing Advances in Wireless Communications, ITALY, Lucca, IEEE, 2024, pp. 6–10, ISBN: 979-8-3503-9319-4. DOI: 10.1109/SPAWC60668.2024.10694523.
- [9] J. Van Mulders, G. Leenders, G. Callebaut, L. De Strycker, and L. Van der Perre, "Aerial Energy Provisioning for Massive Energy-Constrained IoT by UAVs," in *ICC 2022 - IEEE International Conference on Communications*, Seoul, IEEE, Aug. 2022, pp. 3574–3579, ISBN: 978-1-5386-8347-7. DOI: 10.1109/ICC45855.2022.9838284.