Wind Turbine Mounted Base Stations for Coverage Enhancement in Rural Areas

Maurilio Matracia

***Abstract*—Despite global connectivity is one of the main requirements for future wireless networks driven by the United Nation's Sustainable Development Goals (SDGs), the low profit prevents telecommunications providers from investing in rural areas. Hence, designing and deploying affordable solutions for extending the cellular infrastructure to these regions is indispensable.**

Taking advantage of the existing electrical infrastructure spread around the globe, wind turbine-mounted base stations might represent the most sustainable and cost-effective solution to this problem, since no further cell towers, satellites, or aerial base stations (ABSs) would be needed. Indeed, installing full base station (BS) equipment on wind generators would allow to reach sufficient altitudes to ensure line-of-sight (LoS) channels within large areas, without having to build a new infrastructure.

Hereby, a relevant case study is proposed to prove the effectiveness of this solution to stimulate its implementation.

I. Introduction

Improving rural coverage is not an easy task, mostly because of the following reasons:

- Despite they actually power around two million off-grid BSs, diesel generators produce a large amount of CO_2 and thus are not considered as a sustainable source of energy;
- As highlighted in [1], cell towers are often considered an eyesore, and concealing them can cost up to 100 000$. Consequently, promising projects such as Facebook Connectivity's SuperCell might suffer from bureaucratic limitations because of their high visual impact;
- WT aerostats projects providing energy and connectivity, such as "BAT" by Altaeros [2], have been suspended since not economically competitive with the recent drop in oil prices;
- Using ABSs implies privacy issues and risks in case of harsh weather conditions, and both their autonomy and their capability is very limited.

Basing on these considerations, we propose to mount BS equipment on existing WT towers to take advantage of their tall structure, which is usually already connected to both the power grid and the telecommunications network. Our proposed solution is actually dual to the one where a micro WT is mounted on a BS and a battery is introduced to ensure continuous supply. In such case, the height of the transceiver is much smaller and LoS transmissions are rarely achieved for users farther than a hundred meters.

II. The WT-Mounted BS

Whenever wind towers are not already connected to the core network, if the WT is connected to the power grid then Facebook Connectivity's robot, Bombyx, could wrap the optical fiber around overhead power lines [3]. Alternatively, point-to-point backhaul can be used since the nacelles are usually made of RF-transparent glass fiber-reinforced plastic and are voluminous enough to host also the backhaul antennas.

The power consumption of the typical BSs equipment equals 5-10 kW (including radiofrequency equipment, cooling system, digital signal processor, and AC/DC converter [4]), hence it would be a negligible load for either the power grid or the WT itself if equipped with a battery. Finally, the installation inside the nacelle would not generate any visual pollution and consequent bureaucratic issues.

III. Proof of Concept

Population density maps have been carefully analyzed to understand whether the site is dense enough to justify the cost for equipping the WTs. We also considered the BS density, since well-connected areas might not need further improvements. Finally, we took into account the density of existing WTs and thus we chose a site that refers to an under-connected rural area in northern Germany rich in WTs (Fig. 1), for which the population density and the location of the cell towers are also illustrated for a larger surrounding area[1].

Fig. 2 shows that by equipping all the WTs with the same transceivers of the cell tower, it is possible to improve the average coverage probability by 22%, mainly because of the higher altitude and the better planar distribution compared to the cell towers, which eventually results in a higher LoS probability [8] and thus a better communication channel.

References

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The author is with Computer, Electrical, and Mathematical Sciences and Engineering (CEMSE) Division at King Abdullah University of Science and Technology (KAUST), Thuwal, 23955-6900, KSA (email: maurilio.matracia@kaust.edu.sa).

[1] The locations of the cell towers have been extracted from [5], whereas [6] provided the population map and the wind turbine's locations refer to [7].

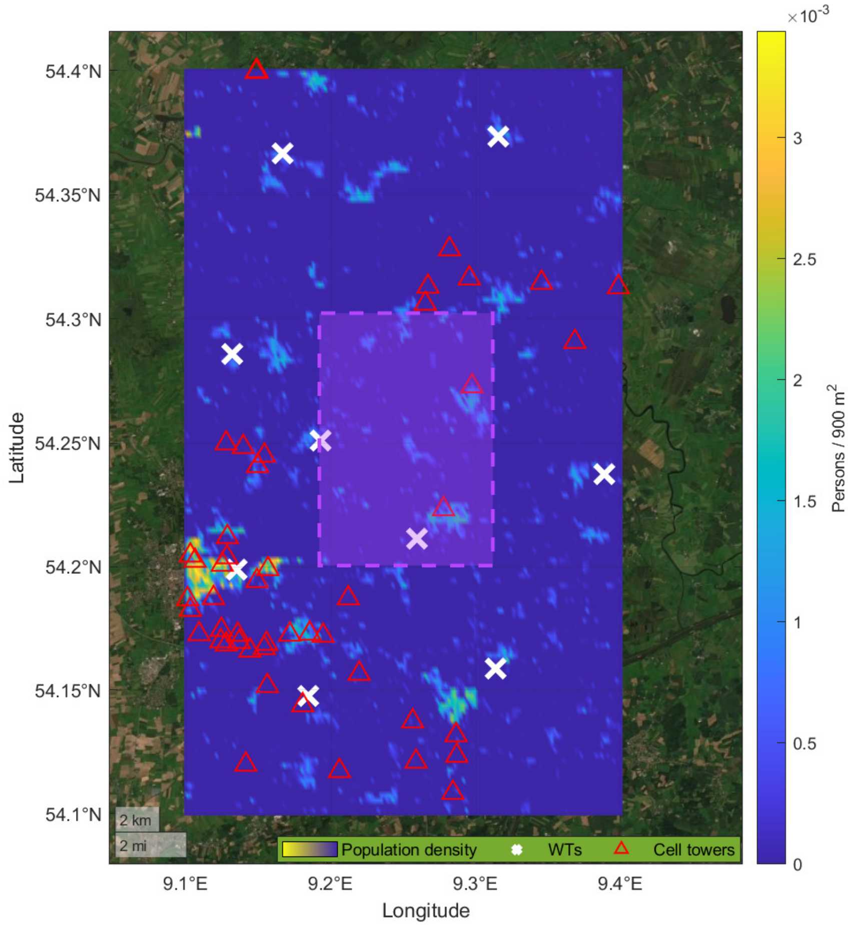

Fig. 1: System setup considered for the case study in a $73\,\mathrm{km}^2$ rural area in northern Germany, highlighted in purple. According to the available data sets, UMTS cell towers are concentrated in the bottom-left corner of the environment considered, whereas wind towers are distributed quite uniformly over the whole region.

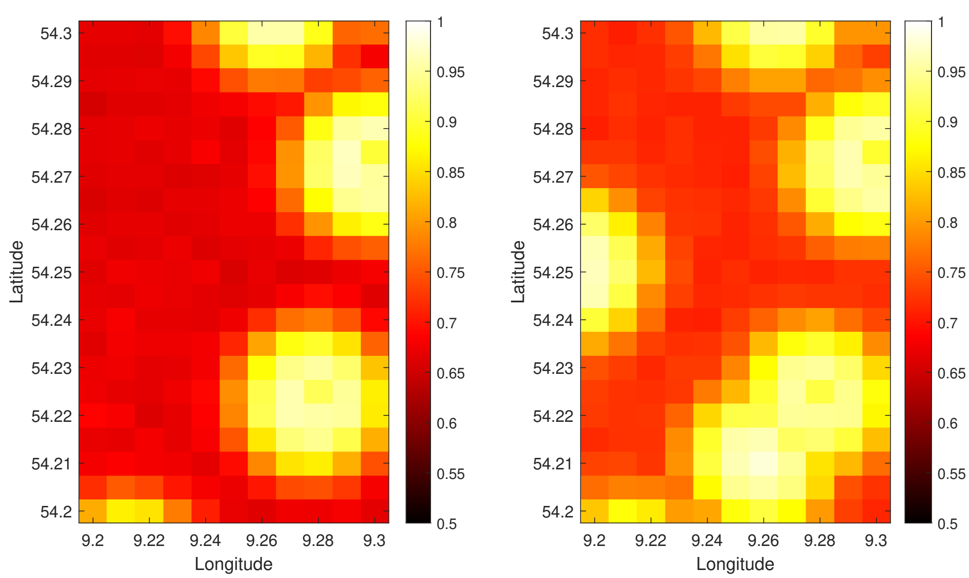

Fig. 2: Coverage probability heat map for the proposed case study in northern Germany when none of (on the left) or all (on the right) of the wind towers are equipped with cellular transceivers. Simulation results have been averaged out of 10^4 iterations.