A scheme for hybrid access point (H-AP) deployment in smart cities

March 10 2020, by Ingrid Fadelli

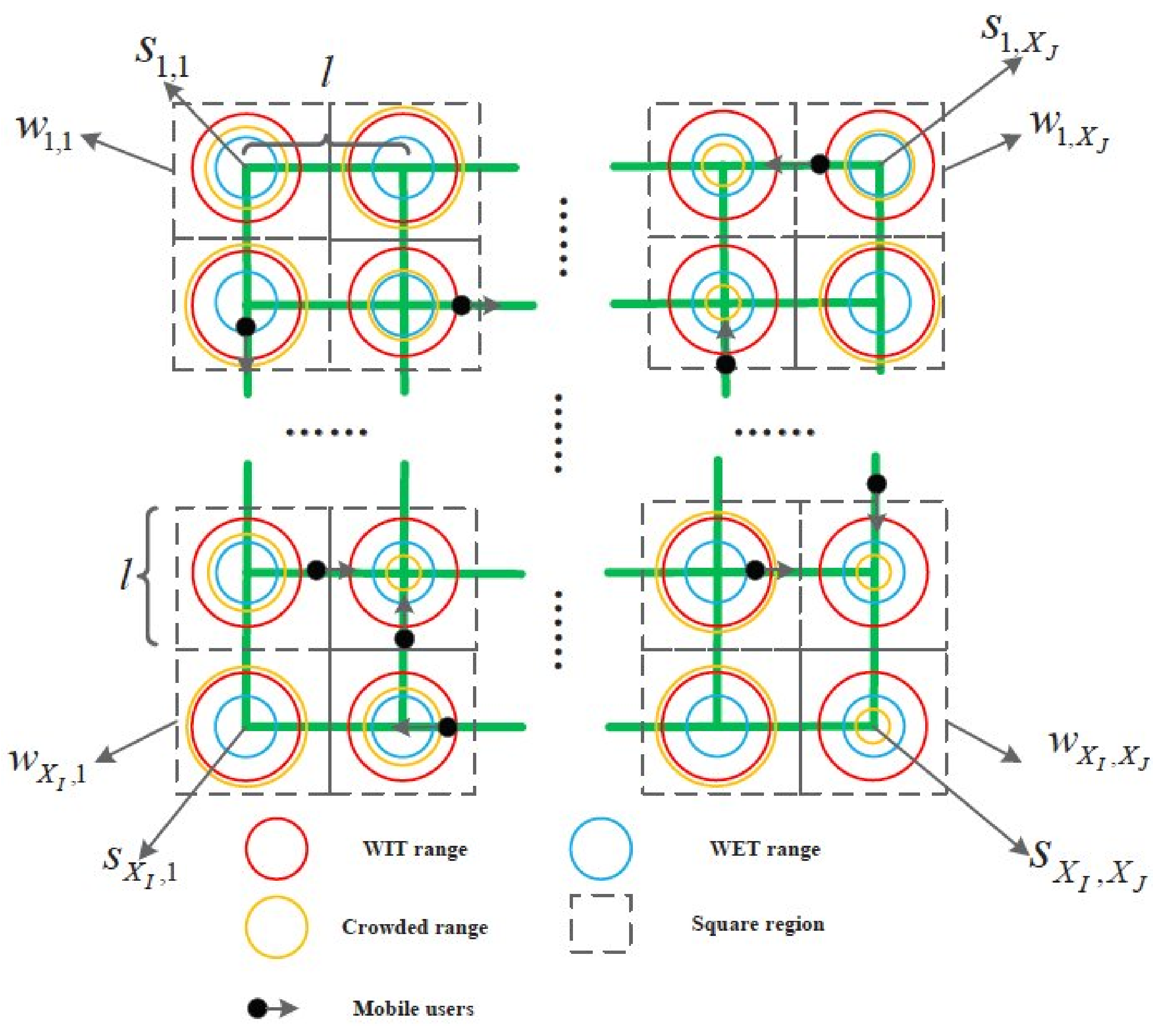


Figure illustrating the smart city environment considered by the researchers' H-AP deployment scheme. Credit: Zhao et al.

Researchers at the University of Essex, UESTC-China and ZTE have recently introduced a scheme for the deployment of hybrid access points (H-APs), which could simultaneously enable wireless information transfer (WIT) and wireless energy transfer (WET) in smart cities. This unique scheme, presented in a paper pre-published on arXiv, uses a mobility model of grid-based streets in urban environments to represent the movements of users navigating a city.

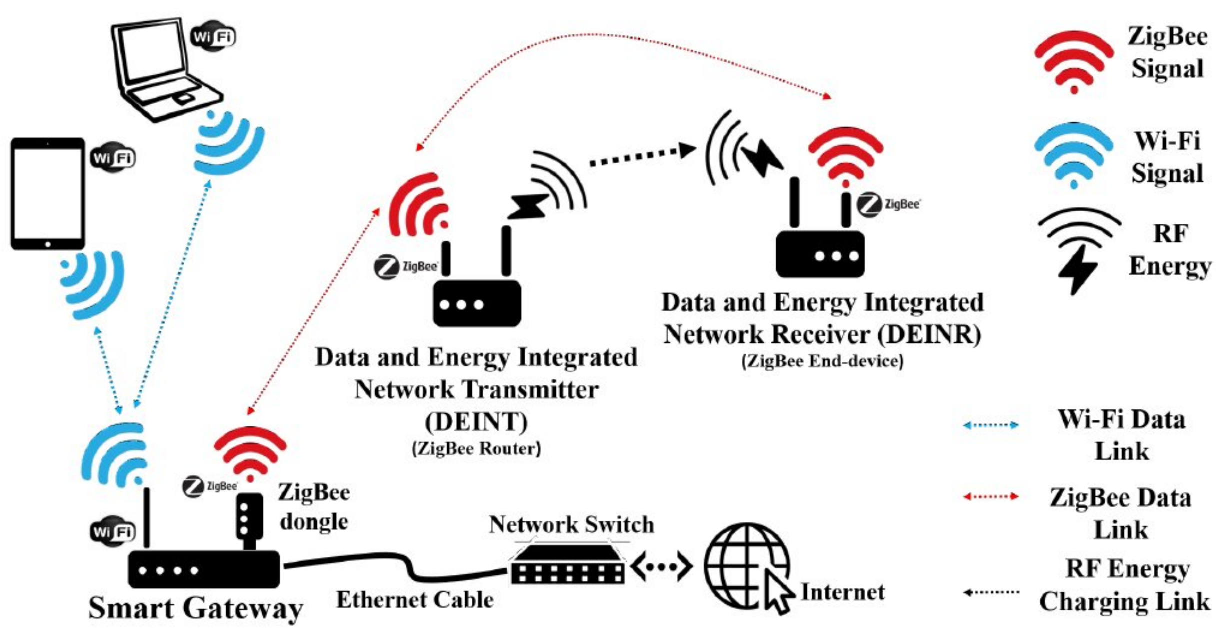
With the large-scale deployment of 5G and the continuous evolution of mobile communication systems, most energy-consuming applications, including video streaming services, AR/VR transmissions, and much more, now run on mobile devices powered by batteries. This results in great energy expenditure and quickly draining batteries, causing interruptions and poor user experiences.

A growing number of people worldwide are now also using small Internet of Things (IoT) devices, such as temperature/PM2.5 sensors, smart watches, fitness trackers and other devices, with an average density of one device per square meter. These small devices can only be equipped with batteries that have low capacity and thus drain much faster. The new scheme proposed by the researchers at the University of Essex, UESTC and ZTE could help to tackle some of these challenges.

"Frequently replacing batteries for IoT devices result in unaffordable maintenance costs for network operators," Jie Hu of UESTC, one of the researchers who carried out the study, told TechXplore. "Therefore, we need to find controllable, on-demand charging methods to provide continuous service experiences, reducing maintenance costs and extending network lifetime."

Technologies that harvest energy from readily available sources (e.g., the sun or wind) could power communication devices in ways that are cheaper and more sustainable. However, these tools are heavily reliant on their surrounding environment. For instance, devices powered by solar energy may be unable to gather enough energy on cloudy or rainy days.

To tackle the challenge of continuously charging small electronics, over the past few years, some companies have also developed near-field wireless charging techniques based on inductive coupling or magnetic resonance, which can be used to charge mobile phones without a plug. For these methods to work, however, the charger and charging device should be at a few centimeters from each other, which ensures effective wireless power transfer.



A basic network topology for the DEIN designed by the researchers. Credit: Zhao et al.

This makes these techniques impractical for continuously supplying energy to large numbers of IoT devices from a distance. A far more practical and feasible solution, explored by the researchers in their study, could be the use of radio frequency (RF) technology.

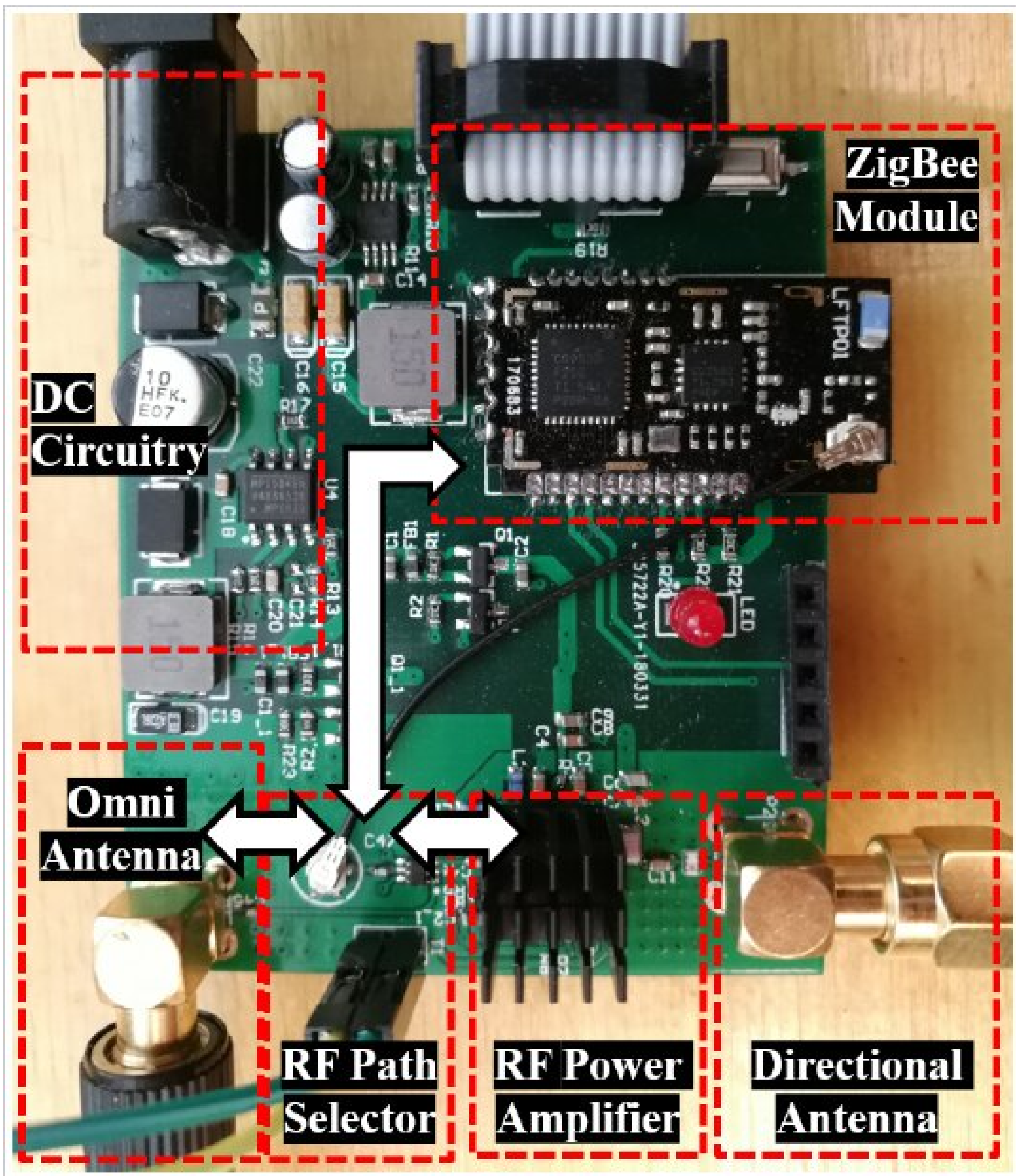
"RF signals are capable of carrying energy to devices in far field," Hu explained. "Moreover, RF-signal-based wireless power transfer (WPT) is a flexible, controllable, on-demand and low-cost solution to supply energy to mobile users and IoT devices. We may adjust the beam width to achieve point-to-point WPT or to simultaneously satisfy multiple devices' wireless charging requests."

The scheme proposed by Hu and his colleagues involves devices that actively request WPT services. The infrastructure can then respond to such requests by transferring the required amount of energy, allowing devices to use resources of the communication infrastructure without the need for additional hardware.

"Exploiting RF signals and the broadcasting nature of wireless channels can enable the simultaneous realization of wireless information and power transfer in the same spectrum, substantially improving the spectrum efficiency," Hu said. "In our research, we propose an optimal H-AP deployment scheme for the sake of satisfying mobile devices' information downloading requests and wireless charging requests."

The key difference between a hybrid access point (H-AP) and a traditional access point (AP) is that the former enables both WIT and WPT services. In their study, the researchers focused on the mobility patterns of devices moving along the streets of urban environments and taking arbitrary turns at crossings. Their scheme for H-AP deployment considers the popularity of road crossings, as network connections tend to slow down when users reach particularly crowded crossings.

"A very meaningful problem is faced by network operators: Given a limited number of H-APs, how can we deploy them in the city so that the WIT and WPT performance can be optimized?" Hu said. "In order to solve this problem, we have designed three deployment schemes, namely WIT-oriented deployment, WPT-oriented deployment and a balanced deployment scheme."



A DEIN transmitter and receiver. Credit: Zhang et al.

The H-AP deployment scheme developed by the researchers uses a mobility model of streets in an urban environment to characterize the movements of communication device users. Firstly, it analyzes the impact of the popularity of a given road crossing or site in the city on WIT and WET efficiency. Subsequently, it implements a balance between the efficiency of WIT and WET services, as part of what the researchers call the "B-deployment' scheme.

"The mobility and distribution of WIT devices and WPT devices as well as the popularity of road crosses, has substantial impact on our design," Hu said. "Our scheme allows us to achieve a balance between WIT and WPT."

The main advantage of the scheme designed by Hu and his colleagues is that it is highly flexible and can satisfy the wide range of qualities of service (QoS) of WIT and WPT services. Findings gathered in a series of experiments testing the new scheme suggest that implementing H-APs in particularly crowded city sites can enable better WIT and WPT performances.

The study is the first to propose a scheme for the large-scale deployment of H-APs in smart cities. In the future, this scheme could help to optimize information and energy coverage of communication networks in busy urban environments.

"In our future work, we plan to carry out an information theoretical analysis for integrated WIT and WPT in order to identify the performance limit," Prof. Kun Yang of University of Essex, another researcher involved in the study, told TechXplore. "We would also like to pursue transceiver design in the physical layer, including coding, modulation, MIMO beamformer and combiner design aiming for improving single user or multiple users' performance of integrated WIT and WPT."

In their next studies, Hu, Yang and their colleagues plan to tackle several other research directions, for instance, investigating the use of resource allocation and access control to support large amounts of devices in communication networks. In addition, they wish to study space-terrestrial networks for the integration of WIT and WPT, which could help to enhance WIT and WPT preformances in UAVs navigating rural environments or areas affected by natural disasters.

"Another goal for further research will be to explore the possibility of 6G-aided WIT and WPT," Yang said. "We will investigate integrated WIT and WPT in TeraHz, with holographic radio and with AI-aided intelligent control. Our ultimate research objective is to create a novel data and energy-integrated communication network (DEIN) in order to realize energy self-sustainability."

More information: H-AP deployment for joint wireless information and energy transfer in smart cities. arXiv:2002.09098 [eess.SY]. arxiv.org/abs/2002.09098

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