success of $P_{th}$. As expected, once the link distance overcomes the critical value around 25 cm, the required transmit power becomes constant. The dashed region corresponds to the typical operational region. In Fig. 7, the minimum required transmit power for an outdoor scenario is shown as a function of the distance. The system parameters are set as in Fig. 6. It can be observed that, unlike an indoor scenario, in an outdoor scenario the minimum required transmit power is an increasing function of the distance (in fact, there are no reflections from surrounding objects).

On the basis of the results presented in Fig. 6 and Fig. 7, the following observations can be carried out. The value of $P_{th}$ plays a limited role on the minimum transmit power. If the transmit power is constrained by energy concerns, only short-range communications (some tenths of centimeters) will be possible: therefore, a multi-hop network architecture is to be preferred. Finally, in an indoor environment, as can be seen from Fig. 6, the reflections from the surrounding environment make the minimum transmit power become constant when $d \geq 25$ cm.

In the remainder of this work, we will consider only interference-limited BANs, i.e., scenarios where condition (23) is satisfied. Formally, this is equivalent to assuming that $N_0 B \ll P_{int}$.

### IV. TREE TOPOLOGIES AND MULTI-HOP COMMUNICATIONS

#### A. BAN Tree Topologies

In [35], a preliminary performance analysis of BANs with star topologies was carried out. Indeed, these topologies are well-suited for medical applications since they exhibit low-power consumption [36] and can perform application-specific data aggregation [37]–[39]. However, in order to limit the transmit power, the use of tree (hierarchical) BAN topologies is appealing.

In Fig. 8, an illustrative tree topology is presented. It can be observed that, in a generic situation, multiple hierarchical levels have to be considered due to the existence of multiple measurement clusters. Each cluster has a cluster-head, which collects the data from its sensors (and its own data) and transmits them to the final sink. We assume that the links in each cluster are short (i.e., each cluster is in a regime of close-range interferers) and the links from the cluster-head to