Fig. 11: Per link throughputs for the three considered strategies in an outdoor environment.

Each other and, therefore, the throughput of the sink reaches a maximum at \( q \approx 0.1 \) and, then, decreases. It can be observed that the maximum throughput at the sink with Configuration B is approximately equal to that with Configuration A. However, unlike Configuration A, in Configuration B there is no interval of \( q \) where the throughput at the sink tends to remain constant. In other words, this configuration does not support, at network level, a larger interval of values of \( q \).

The last scheme—denoted as Configuration C (Fig. 9(c))—is highly centralized. Its performance is investigated in Fig. 11(c). As each cluster contains only one leaf node, \( \tau_{\text{leaf}} \) is highest. On the other hand, the relays interfere with each other while communicating to the sink and, therefore, \( \tau_{\text{relay}} \) remains very low (its maximum value is around 0.05). As a consequence, \( \tau_{\text{sink}} \), after reaching its maximum value for \( q \approx 0.08 \) (similarly the previous configuration), tends to decrease to zero much faster than in Configuration B. Note that the maximum value of the throughput at the leaves is close to the maximum value of the throughput at the sink. Finally, note that for \( q \geq 0.5 \), even if \( \tau_{\text{leaf}} \) is high, \( \tau_{\text{sink}} \) is basically zero: in other words, no data transmitted by the leaves can be successfully transmitted by the sink to an external controller (e.g., through 3G communications).

C. Throughput in Indoor Scenarios

In Fig. 12, the per-node throughputs at the various hierarchical levels are presented for the three topologies of interest. As a first, general, observation, it can be seen that the per-node throughputs are much lower in indoor scenarios than the corresponding ones, shown in Fig. 11, in outdoor scenarios. This can be explained by the presence of reflections off the limbs and the surrounding objects. Indeed, the initial antenna gain (at \( d = d_{\text{ref}} \)) is about \( L_{\text{ref}} = -57.42 \) dB and this value is not very different from the gain of the environment, i.e., \( L_{\text{DB}}^{\text{env}} = -78 \) dB. Therefore, short links are less affected (since the received signal power is much stronger than the reflected power), while longer links are more likely to suffer of significant interference from the reflected waves. This was not the case in outdoor scenarios where distant nodes did not contribute to the interference thanks to the high path loss coefficient (i.e., \( \gamma = -124 \) dB/m).

Regarding Configuration A, it can be seen from Fig. 12(a) that the leaves can support a wide range of values of \( q \) (i.e., the throughput is non-zero for any value \( q \in (0, 0.6) \)). As anticipated in the description of the results in outdoor scenarios, the relays effectively cumulate the leaves’ and their own data, guaranteeing the highest throughput almost for all values of \( q \)—for very low values of \( q \), \( \tau_{\text{rel}} < \tau_{\text{sink}} \). However, the last links (i.e., the relay-to-sink links) are subject to strong interference due to the reflections off the surrounding environment and the sink throughput is much lower than in the outdoor scenario. More precisely, the throughput reaches a maximum at \( q \approx 0.05 \) and becomes insignificant for \( q \geq 0.3 \).

The performance of Configuration B is presented in Fig. 12(b). Since the tree is more balanced than in Configuration A (i.e., there are less leaves and more relays), the performance observed at the leaves is better in terms of throughput. However, the increase of the amount of relay nodes and the fact that these are more subject to environment interference (since these are considered as long links) makes the throughput decrease significantly. Finally the throughput at the sink remains limited, compared to the outdoor scenario, for the reasons described previously in analysis of the Configuration A.

The third configuration—namely, Configuration C—is shown in Fig. 12(c). In this configuration, the throughput at