scheme with the same obstacle density, and the SBP is improved by more than 20% when $D_\mu = 3$ and the obstacle density is high. Because of such substantial benefits on throughput performance, it might be worth adopting HTMR despite its added complexity.

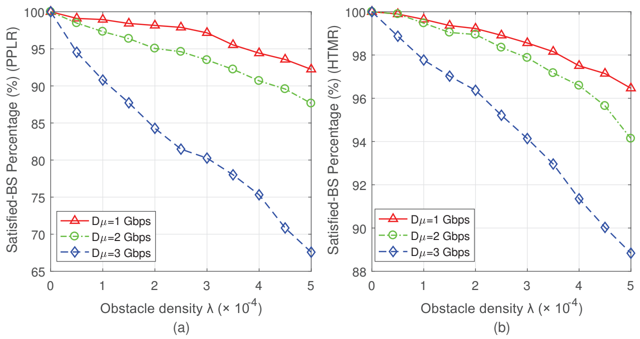

Figure 11: SBP for PLLR and HTMR with different D_μ.

5.3 Hop-constraint effects

Our problem formulation assumes that each eligible backup path selected for a specific backhaul path should satisfy a hop-number constraint, i.e., the total hops (including dedicated relays and relayed-SBSs) along this path must be fewer than a hop-number threshold H. Here we investigate how this H affects network survivability. With the obstacle density $\lambda = 1.2 \cdot 10^{-4}$ and data demand at each SBS of around 1 Gbps, Fig. 12 shows that the BNS will increase as H increases for all reconfiguration approaches except the LLR scheme. This is because with larger H, more backup paths for each backhaul path are put in the SS, which improves the network-level reconfiguration, but this has no effect on a purely link-level reconfiguration approach. In addition, by increasing H, PLLR and HTMR can even provide nearly 100% BNS, and NLR can also possibly provide better blockage tolerance than LLR. However, a larger H results in higher end-to-end latency and, therefore, this trade-off between latency and robustness in the network would need to be carefully considered with respect to application latency requirements.

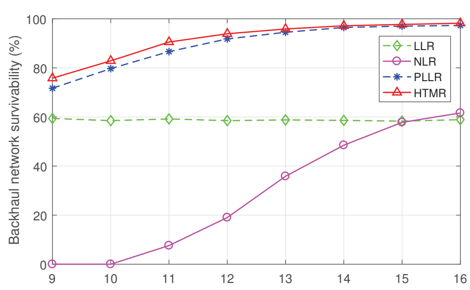

Figure 12: BNS comparisons with different schemes vs. constrained hop number H.

6 CONCLUSION

In this paper, we considered the problem of survivability in mmWave backhaul networks, where a single A-BS serves as a gateway for a number of SBSs and relays deployed along urban streets. In such a scenario, joint link-level and network-level reconfiguration schemes are proposed to overcome blockage and failure effects. These schemes combine relay path reconfiguration with alternate backup paths for fast path recovery. Through simulation results, the performance of proposed schemes is shown to be always superior to purely link-level/network-level reconfiguration schemes. The approaches can provide a substantial improvement in backhaul network survivability, and also maintain backhaul throughputs, achieving the Gbps data demand for each SBS even in the presence of multiple blockages/failures. Future research will focus on path recovery in other network topologies of urban environments.

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