

# Weak Many vs. Strong Few: Reducing BER through Packet Duplication in Power-Budgeted Wireless Connections

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**Abstract:** In this paper we present new energy-aware techniques to lower the packet-level error rates of application-layer connections in wireless ad-hoc networks. We consider a model in which each connection is allocated a fixed power budget, and ask: Is it better to use this power budget to send many duplicate packets (at lower power) or fewer (e.g. just one) packets (at high power)? We consider a scheme in which each application-layer connection is implemented at the physical level by an overlay network consisting of multiple parallel multi-hop paths. Data packets submitted at the connection source are checksummed and replicated, flowing breadth-first across the overlay network towards the destination. The destination delivers the first error-free copy of each packet, in order, to the application layer, dropping packets that are corrupt or duplicate. We compare this overlay scheme with the traditional scheme in which the source transmits precisely one packet to the destination along a single minimum-hop path. We show that even when the two schemes are constrained by *identical power consumption bounds*, the overlay scheme can use duplication to attain significantly lower packet-level error rates in many common situations. We describe the relationship between packet error rate, the extent of duplication, and the lengths of the paths, and show that the qualitative nature of the relationships change significantly, depending on available power budget.

**Keywords:** wireless ad-hoc networks, overlay network, lower bit error rate, minimum energy consumption, node disjoint paths.

- C.-K. Toh, "Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks", *IEEE Communications Magazine*, June 2001.
- Christine E. Jones and Krishna M. Sivalingam and Prathima Agrawal and Jyh Cheng Chen, "A Survey of Energy Efficient Network Protocols for Wireless Networks", *Wireless Networks* 7, 343- 358, 2001.
- Q. Li and J. Aslam and D. Rus, "Online Power-aware Routing in Wireless Ad-hoc Networks", *Proceedings of ACM Mobicom 2001*, pp97-107 .
- Jian Tang and Guoliang Xue and Weiyi Zhang, "Energy Efficient Survivable Broadcasting and Multicasting in Wireless Ad hoc Networks", *MilCom'04*.
- Jian Tang and Guoliang Xue, "Node-Disjoint Path Routing in Wireless Networks: Tradeoff between Path Lifetime and Total Energy", *IEEE Communications Society*, 2004.
- Suman Banerjee and Archan Misra, "Energy Efficient Reliable Communication for Multi-hop Wireless Networks", *Journal of Wireless Networks (WINET)*, 2004.
- Qunfeng Dong and Suman Banerjee, "Minimum Energy Reliable Paths Using Unreliable Wireless Links", *MobiHoc'05, Urbana-Champaign, Illinois*, May 25-27, 2005.
- Anand Srinivas and Eytan Modiano, "Minimum Energy Disjoint Path Routing in Wireless Ad-hoc Networks", *MobiCom'03, San Diego, California*, September 14-19, 2003.
- Shibo Wu and K. Selcuk Candan, "GPER: Geographic Power Efficient Routing in Sensor Networks", *Proceedings of the 12th IEEE International Conference on Network Protocols (ICNP'04)*, 2004.
- Ning Li and Jennifer C. Hou and Lui Sha, "Design and Analysis of an MST-Based Topology Control Algorithm", *IEEE INFOCOM*, 2003.
- G.S. Laurer, "Packet Radio routing", Chapter 11, pages 351-396, Prentice Hall 1995.
- Sergey Loyka and Francois Gagnon, "Performance Analysis of the V-BLAST Algorithm: An Analytical Approach", *IEEE Transactions on Wireless Communications*, Vol.3 No.4, 2004.
- J. G. Proakis, "Digital Communications", McGraw Hill, 2001.
- "WaveLANP/CMCIA Card User Guide", Lucent Technologies.
- "Bluetooth Resource Center".