Performance of ZigBee PRO Mesh Networks with Moving Nodes

Chester Hamilton Varun Sampath

Abstract

Radio modules based off of the ZigBee PRO specification provide cheap and low power wireless communication, via usage of the IEEE 802.15.4 PHY and MAC layers and a network layer mesh routing protocol. We describe various implementation aspects of ZigBee PRO and present performance data on a ZigBee PRO mesh network for point-to-point and multi-hop transmission using XBee-PRO ZB modules. In particular, we present findings on network performance when a node is constantly moving and changing routes. We found that in the worst case where packets are transmitted immediately after the old route is no longer physically possible, extreme packet loss occurs as the network cannot perform route maintenance operations in time. With more gradual movement, however, the network operates without packet loss.

Experimental Setup

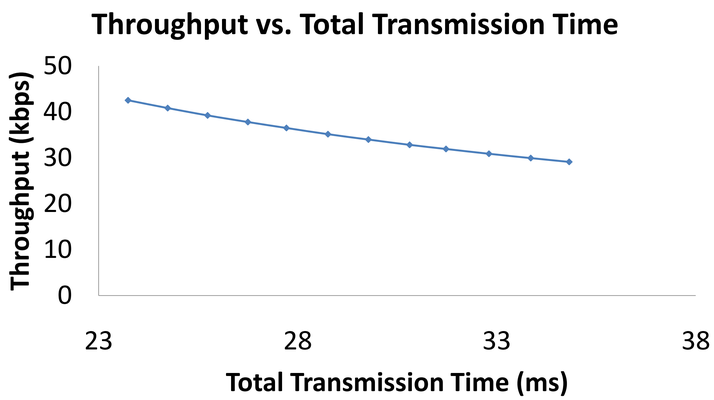
- Java test programs using open source xbee-api
- ZigBee Coordinator to send packets, ZigBee Routers to route and receive
- Sent 3 sets of 1000 packets
- Point-to-Point
  - Modules 1.5 meters apart
- Multi-Hop
  - Two-hop communication
  - Middle Router and Coordinator 20 meters apart
  - Antenna-less Destination Router
- Moving Nodes
  - Coordinator and two Middle Routers
  - "Instantaneous" Movement
    - Antenna-less Destination Router is always out of range of one router and Coordinator during testing
    - Moved Destination Router back and forth between Middle Routers, sending one or two packets immediately after each movement
  - Gradual Transition
    - Destination Router walked in range of one router, then an overlap region, then the other router

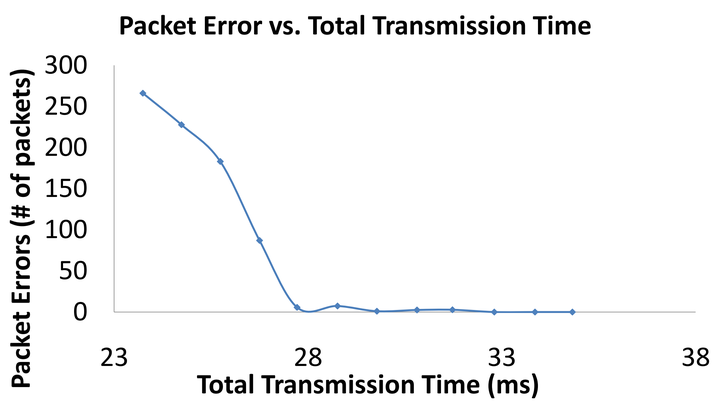
Results

Synchronous Transmissions (wait for ACK before sending again)

Setup	Average Transmission Time (ms)	Error (# packets)	RSSI (dBm)	Throughput (kbps)
PtP-Sync	39.65	0	-41.33	25.67
PtP-Sync-AT	31.86	0	-39.00	31.90
PtP-Sync-noACK	22.06	0	-42.33	45.96
MH-Sync	58.62	0	-84.33	17.44
MH-Sync-noACK	42.13	9	-86.67	24.56
MH-Sync-no-16bit	62.53	0	-81.67	16.39

Asynchronous Transmissions (transmit at regular intervals)





Discussion & Conclusions

- General Thoughts
  - Serial link the bottleneck in transmission
    - Evidenced by API-AT firmware Performance
  - RSSI impacts physical layer throughput
  - Packet Loss with Asynchronous Transmission delays of 27ms and lower imply physical layer slower than 250kbps
- "Instantaneously" Moving Nodes (No data shown)
  - Possible 100% packet loss if one packet transmitted immediately after each move
    - Periodic one-hop link refreshing not fast enough to detect broken link
    - Waiting 15 seconds for route maintenance operations to complete results in no packet loss
- Gradual Transition Moving Nodes (No data shown)
  - Enough time for reassociation when moving between routers
  - Minimal packet loss

Applications

- Multiple mesh-networked UAVs with low power/range radios

Acknowledgements

We thank Drs. Saad Biaz and Richard Chapman of Auburn University for their guidance and help in securing materials for research. This work was funded by NSF Award #0851960.