# Intelligent Cooperative Ad-Hoc Mesh Networks

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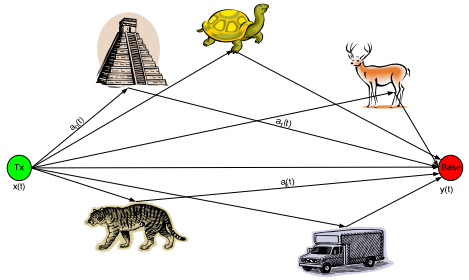
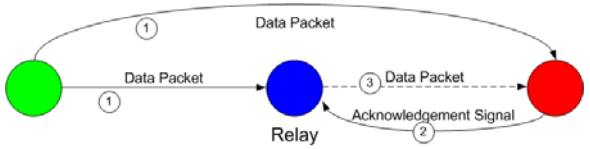
## Introduction




- Design an intelligent, cooperative wireless mesh network protocol
- Measure transmission efficacy in a variety of environments for both direct- and cooperative- network protocols
- Determine optimal relay positioning for the cooperative protocol
- Analyze power efficiency for both protocols




1) Source transmits data packet to Relay and Base every *t* milliseconds.
2) Base signals to the Relay if it has successfully received a packet from the Source.
3) Relay retransmits packet to the Base only if it has not received the acknowledgement signal from the Base within *t*/2 milliseconds.

## Optimal Relay Placement

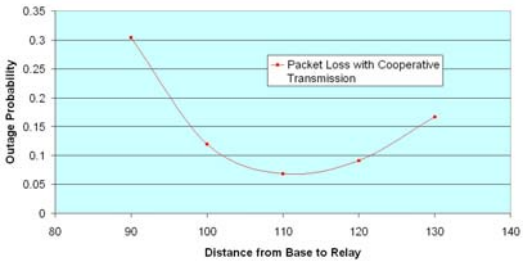
Constrained Optimization Problem

$$P_o = P(SNR(r) \le \gamma)$$

$$P_{oc}(r_{sd}, r_{sl}, r_{ld}) = \left(1-\exp\left(-\frac{N_o \gamma r^{\eta}_{sd}}{KP_{TC}}\right)\right)\left(1-\exp\left(-\frac{N_o \gamma (r^{\eta}_{sl} + r^{\eta}_{sl})}{KP_{TC}}\right)\right)$$

$$r^*_{sl} = \arg\min_{r_{sl}} P_{oc}(r_{sd}, r_{sl}), \forall\, 0 \le r_{sl} \le r_{sd}$$

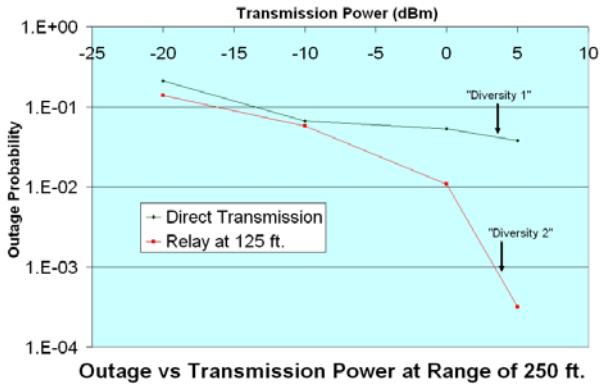
Solution: $r^*_{sl} = \frac{r_{sd}}{2}$ for $\eta > 1$




## Power Efficiency

- Set base to source distance (250 ft.)
- Fix relay at the theoretical optimal position in the center (125 ft.)
- Vary power levels from -20 dBm to 5 dBm (0 dBm = 1mW)


*Comcast Stadium, University of Maryland*




**Outage vs Transmission Power at Range of 250 ft.**

## Spatial Locality

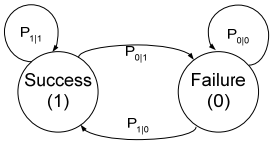
$$y(t) = \sum_{i=1}^{N} a_i(t)x(t-\tau_i) + \xi(t) \approx x(t)\sum_{i=1}^{N} a_i(t) + \xi(t)$$

x(t): signal sent from source or relay
y(t): signal received at base or relay
$a_i(t)$: channel fading coefficient
$\tau_i$: channel delay
$\xi(t)$: additive noise

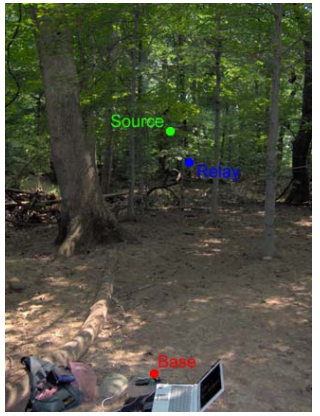

*Parking Lot 6 (Comcast Garage), University of Maryland, College Park*

## Temporal Locality

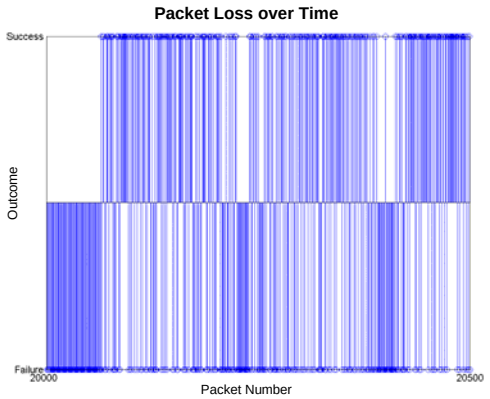
- Conditional probability modeling using two-state Markov chain




- Calculated from experimental results:
  $P_{0|0} = 0.5015$, $P_{0|1} = 0.4207$
  $P_{1|0} = 0.4985$, $P_{1|1} = 0.5793$
- High values for $P_{0|0}$ and $P_{1|1}$ indicate bursting behavior, low values indicate transitions




*Paint Branch Trail, University of Maryland, College Park*




## Conclusions

- The relay position for which packet loss is minimized is at the exact middle between the source and the base
- **Diversity 1** packet loss is observed with **direct transmission** of packets over varying power levels; **diversity 2** observed with **cooperative transmission**
- Small variations in relay placement greatly affect quality of service (QoS)
- Packet loss occurs fairly randomly when loss is high (~40%+)