Scaling Cooperative Diversity to Large Networks

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Cooperative Diversity via Distributed Array (Laneman)

- Spatial diversity through antenna array.

- Cooperative diversity through virtual antenna array.

Wireless relaying
Virtual receiving antenna arrays
Receiver #1
Receiver #2
Geographic Random Forwarding (Zorzi & Rao)

- The GeRaF protocol.
  - Source node broadcasts its message without picking the relaying node a priori.
  - A contention scheme assures that the node closest to the destination acts as relay.
  - Especially suitable for sensor networks with nodes that cycle in and out of sleep states.

R: RTS packet; C: CTS packet;
D: Data packet; CA: Contention arbitration;
T: network coherence time (time that topology is fixed);
Hybrid ARq Based INtra-cluster GEographic Relaying

- **Drawback of GeRaF.**
  - Excessive message delay in low (active node) density networks.

- **The HARBINGER Protocol.**
  - Preserve protocol structure and priority zone-splitting mechanism in GeRaF.
  - Utilize hybrid-ARQ to expand coverage radius to $R_M$ ($M$ is rate constraint).
  - Cross-layer protocol combines cooperative diversity, hybrid-ARQ, and routing.

- **Type II hybrid-ARQ retransmission.**
  - Through puncturing, different fraction of a rate $r$ mother codeword is transmitted per time slot $s_m = \{s_1, s_2, \ldots, s_M\}$ where each time slot is of unit duration.
  - Assuming capacity approaching codes and maximum likelihood detection.
  - The accumulated mutual information at $Z_j$: $I_j[m] = \sum_{i=1}^{m} \frac{1}{2M} \log_2(1 + \gamma_j[i])$.
  - Once $I_j[m] \geq r$, $Z_j \in D(s_m + 1)$ and $Z_j$ may act as relay.
  - Once a relay forwards the message, all nodes flush their memory of previous transmissions.
Slow HARBINGER: $T > 1$

R: RTS packet;  
C: CTS packet;  
D: Data packet;  
T: Network coherence time;  
CA: Contention arbitration;

Slow HARBINGER A maximizes message progress.  
Slow HARBINGER B minimizes ARQ packet retransmissions.
Fast HARBINGER: $T = 1$

R: RTS packet; C: CTS packet; A: ACK packet; D: Data packet; CA: Contention arbitration; T: Network coherence time;

Fast HARBINGER during 0~T.

Fast HARBINGER during T~2T.
Figure 1: The message delay in different versions of HARBINGER under rate constraint $M = 2$ and source-destination separation $D = 10$. Transmit power is normalized to $R_1 = 1$ and path-loss coefficient $\mu = 3$. 
Figure 2: The energy efficiency of different versions of HARBINGER under rate constraints $M = 2$ and source-destination separation $D = 10$. 
Conclusions

- HARBINGER is a cross-layer protocol combining cooperative diversity, hybrid-ARQ, and routing.

- Comparison of HARBINGER and GeRaF.
  - HARBINGER is a generalization of GeRaF.
  - GeRaF is HARBINGER with $M = 1$.
  - HARBINGER has shorter delay than GeRaF.
  - HARBINGER requires more transmit energy.
  - HARBINGER allows low sleep duty cycles.

- Different versions of HARBINGER are developed for different network applications.
  - Slow HARBINGER A maximizes message progress, thus minimizes delay.
  - Slow HARBINGER B minimizes data packet retransmission, thus is more energy efficient than Slow HARBINGER A.
  - Fast HARBINGER synchronizes data packet retransmission with device sleeping cycles, thus also benefiting from time diversity.

- Without memory flushing HARBINGER should have much better performance but requires more complicated analysis.
Publications


