Improving Spatial Reuse with Collision-Aware DCF in Mobile Ad Hoc Networks

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Overview

- Introduction
- Related work
- System model & problem statement
- Proposed solution (CAD)
- Simulation
- Conclusions & future work

Introduction

- A key idea of multihop comm. rather than direct comm. is to exploit spatial reuse to improve the spectral utilization
- Tradeoff between Spatial reuse and interference
  - More spatial reuse means more concurrent communications
  - But, it causes more interference
- CAD (Collision-Aware DCF)
  - Increases spatial reusability by encouraging more "exposed terminals" to attempt concurrent communications
  - Alleviates interference influence by "predicting" collisions

Improving Spatial Reuse with Collision-Aware DCF in Mobile Ad Hoc Networks

Related Work

- Interference-avoidance technique
  - DCF of IEEE 802.11: PCS (Physical Carrier Sense) and VCS (Virtual Carrier Sense).

Conservative reservation

- Interference-reduction technique
  - Transmit power control: Apply the lowest necessary transmit power.
  - Directional antenna control: Interference is limited at the direction of receiver.

Aggressive reservation (more collisions)

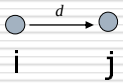
- CAD: collision-aware technique
  - Encourage more concurrent transmissions.
  - Predict collisions between ongoing and pending transmissions.

Optimal reservation

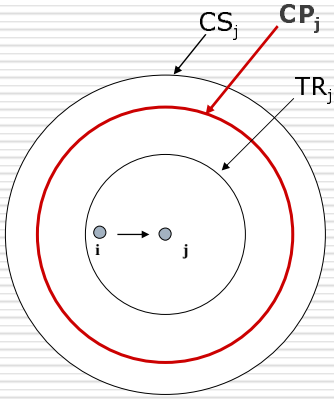
8/15/2005 ICPP 2006, Columbus, Ohio

Radio Propagation Model

- Two-ray ground propagation model



$$P_r(d) = P_t G_t G_r \frac{(h_t h_r)^2}{d^4 L}$$



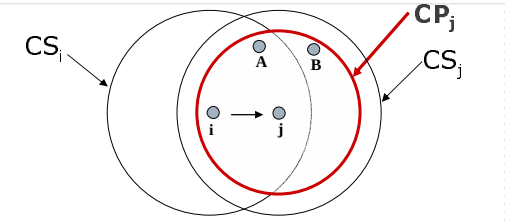
- Reception Model

$$SNIR = \frac{P_r(d_{ij})}{N_0 + \sum_{k \neq i} P_r(d_{kj})} > z_0$$

(z_0: capture ratio)

DCF of IEEE 802.11

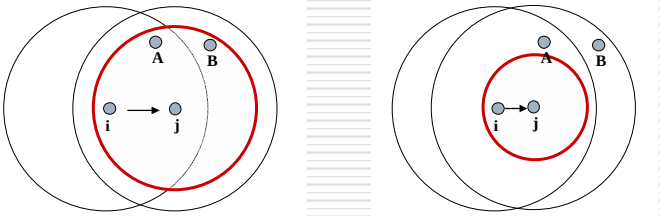
- Carrier sense (CS) based MAC
  - Physical carrier sense (PCS)
    - Hold up transmission if carrier signal is above CS threshold.



  - Virtual carrier sense (VCS)
    - Announce the impending use of the medium.
    - RTS/CTS exchange

Problem Statement

- DCF (PCS & VCS) can avoid collisions but limits the spatial reusability, particularly with short communication distance.



How can we effectively protect a transmission from collisions while allowing more concurrent communications?

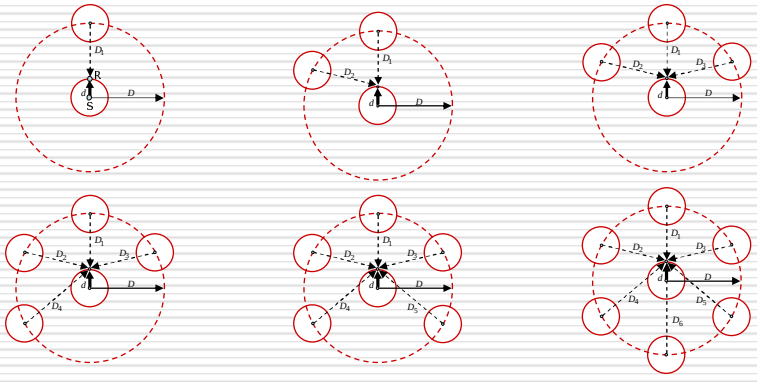
CAD (Collision-Aware DCF)

- DCF reserves
  - more spatial area than necessary
- CAD reserves
  - Minimum necessary spatial area based on communication distance and interference level (REQ_SR)
  - Minimum necessary time period depending on packet size and transmission rate (REQ_TR)
- A key question is how to calculate REQ_SR & REQ_TR ?

Estimation of REQ_SR

- A node that has a pending packet
  - Estimates the optimal REQ_SR_0 which protects the communication
- What influence factors to consider?
  - The shorter the communication distance, the smaller the REQ_SR_0
  - Worst-case interference scenario in terms of
    - Number of interferers
    - Directions of interferers

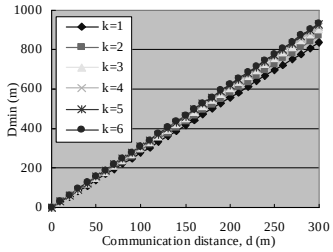
Estimation of REQ_SR

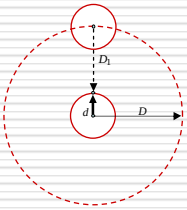


$$D_1 = D - d \qquad D_2 = D_3 = \sqrt{D^2 + d^2 - Dd}$$
$$D_6 = D + d \qquad D_4 = D_5 = \sqrt{D^2 + d^2 + Dd}$$

$$SNIR = \frac{P_r(d)}{N_0 + \sum_k P_r(D_k)} > z_0 \quad \Rightarrow D_{\min}$$

Estimation of REQ_SR(cont.)





- Communication distance d almost dominates the influence.
- Use k=1 to make estimation.

$$D_{\min} = \left(\sqrt[4]{Z_0} + 1\right) \cdot d$$

$$REQ\_SR = P_r\left(D_{\min}\right)$$

Estimation of REQ_TR

- The time period required to protect the communication of the issuing node.
- Comparison between DCF and CAD

	DCF	CAD
Use NAV	Yes	Yes
Where to embed	MAC header	PLCP header
Protected frames	Subsequent frames	Current and subsequent frames
Informed nodes	Less	More

PLCP: Physical Layer Convergence Protocol

Transmission Decision

- A node that has a pending packet
  - Estimates the optimal REQ_SR_0 which protects the communication
  - There is an ongoing communication,
    - the spatial requirement of which is REQ_SQ and
    - its received signal strength is RSSI
- Should the node transmit its own?
  - It increases spatial utilization
  - But it risks potential interference

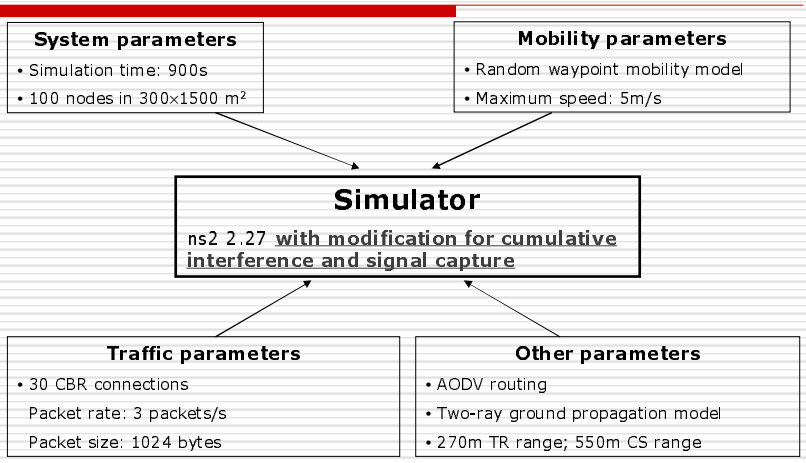
Transmission Decision (Cont'd)

- DCF of IEEE 802.11
  - If (RSSI ≥ CS threshold),
  - Then, the node considers medium busy and does not transmit its own
- CAD
  - If (RSSI ≥ REQ_SR) — Protect ongoing comm.
  - or (RSSI ≥ REQ_SR_0), — Protect its own comm.
  - Then, the node considers medium busy and does not transmit its own

Transmission Decision (Cont'd)

- DCF of IEEE 802.11
  - If (NAV > 0),
  - Then, the node considers medium busy and does not transmit its own
- CAD
  - If (NAV > 0),
  - Then, the node considers medium busy and does not transmit its own
  - NAV is updated according to REQ_TR.

Simulation Environment



End-to-end Performance Comparison with Different Mobility

DCF2

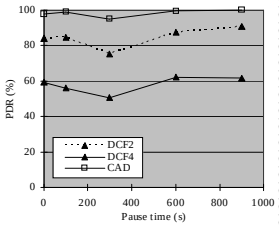
DCF with two-way handshake (without RTS/CTS)

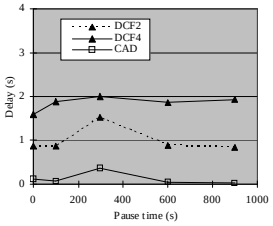
DCF4

DCF with four-way handshake (with RTS/CTS)

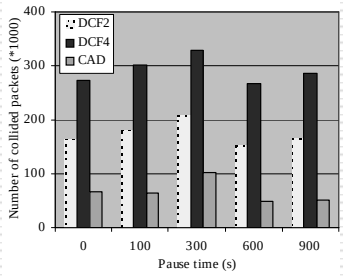
CAD

With two-way handshake (without RTS/CTS)

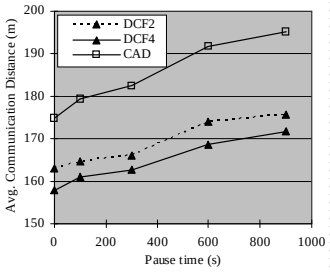




Per-hop Performance Comparison with Different Mobility

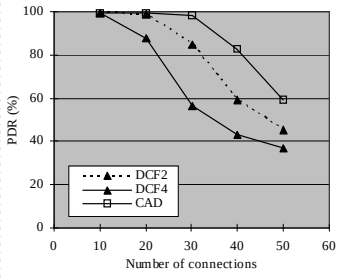


CAD is more collision aware than DCF

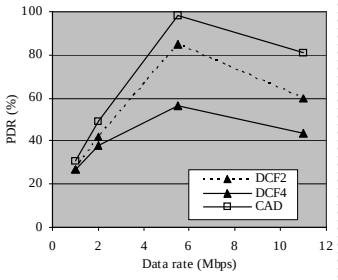


CAD can make longer-distance link more reliable

Effect of Traffic Intensity and Data Transmit Rate



CAD still outperforms DCF no matter traffic is light or heavy



A higher data rate does not always produce better end-to-end performance

Conclusions and Future Work

- Conclusions
  - CAD encourages more concurrent transmissions but at the same time avoids collisions more effectively.
  - The benefits of CAD come from
    - Dynamically adjusting spatial and time reservations based on communication distance, packet size, and packet type
    - And, embedding the reservation requirements in PLCP header, so that more nodes can be informed and aware of collisions to ongoing communications.
- Future Work
  - Combine CAD with TPC and TRC schemes.

THANK YOU !