CS 525M – Mobile and Ubiquitous Computing Seminar

Fan Wu

Using Directional Antennas for Medium Access Control in Ad Hoc Networks

Romit Roy ChRoudhury, Xue Yang, Ram Ramanathan
and Nitin H. Vaidya
Dept. of Electrical and Computer Engineering, and Coordinated Science Laboratory
University of Illinois at Urbana-Champaign

Internetwork Research Department
BBN Technologies (A Part of Verizon)

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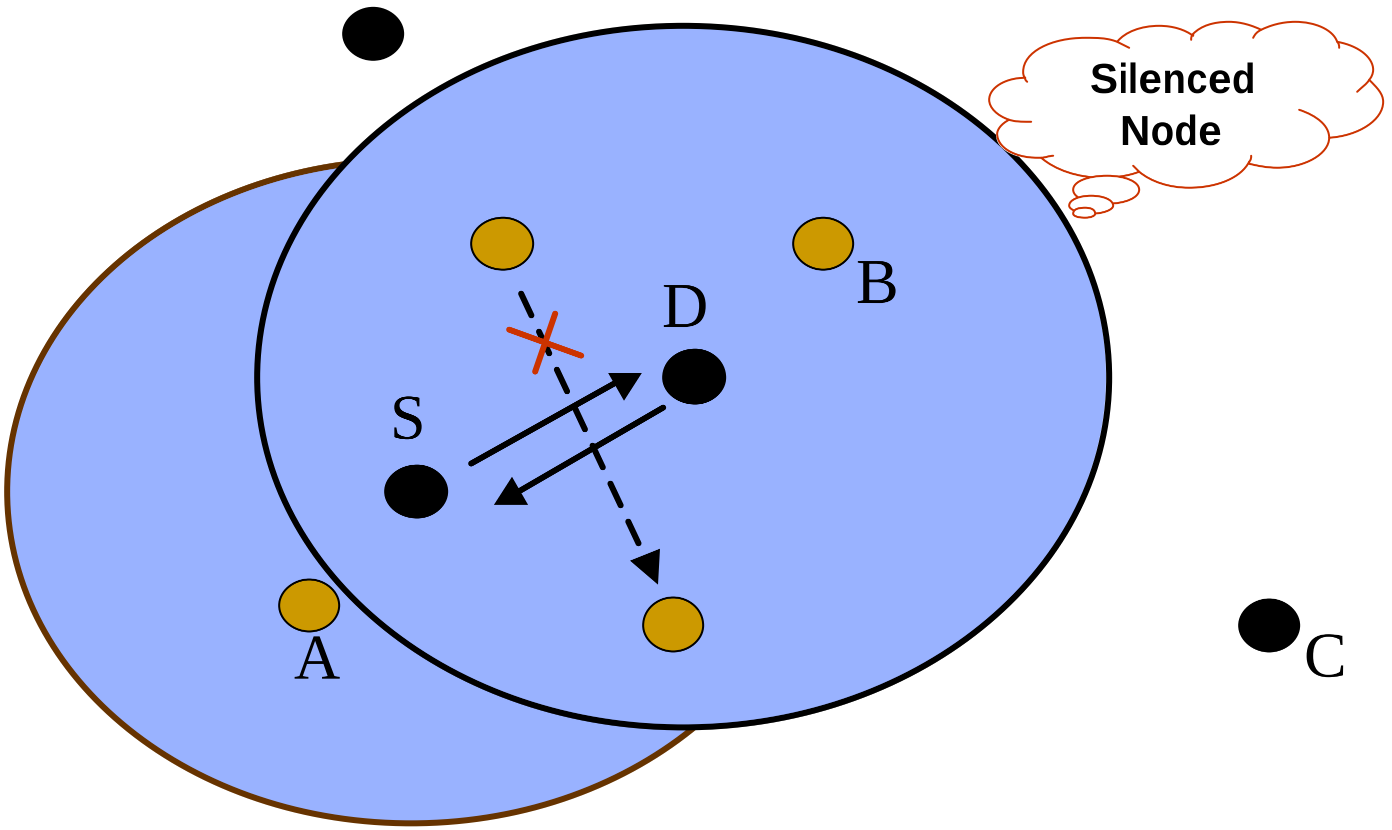
Contents

Introduction

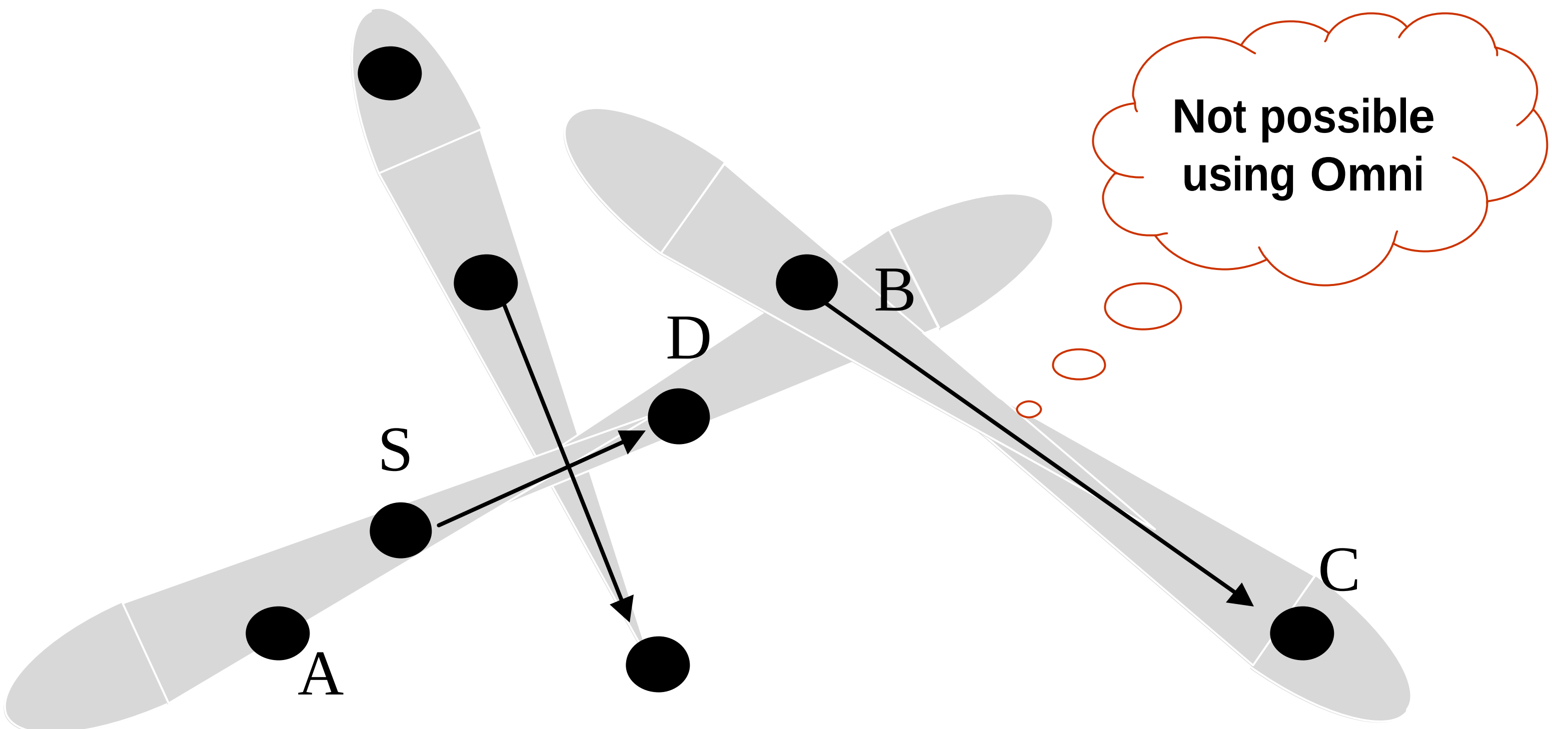
- The Problem of utilizing directional Antennas to improve the performance of ad hoc networks is non-trivial
- Pros
  - ✓ Higher gain (Reduced interference)
  - ✓ Spatial Reuse
- Cons
  - ✓ Potential possibility to interfere with communications taking place far away

Using Directional Antennas for MAC in Ad Hoc Networks

Omni-directional Antennas



Directional Antennas



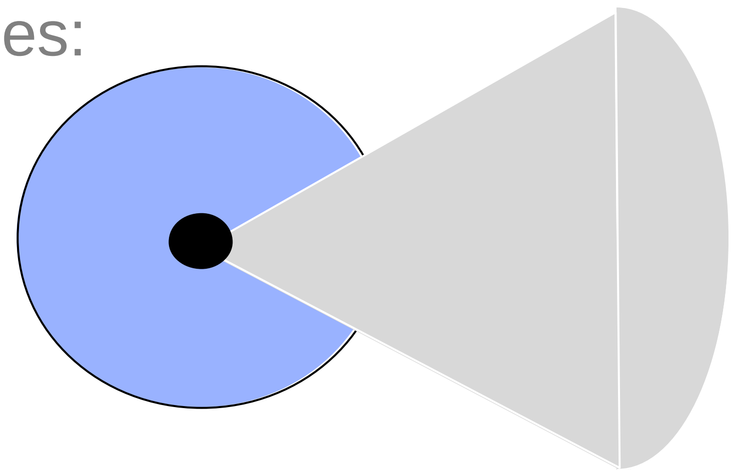
Related Works

- MAC Proposals differ based on
  - ✓ How RTS/CTS transmitted (omni, directional)
  - ✓ Transmission range of directional antennas
  - ✓ Channel access schemes
  - ✓ Omni or directional NAVs
- Gain of directional antennas is equal to the gain of omni-directional antennas

Preliminaries

- Antenna Model
  - ✓ Two Operation modes:

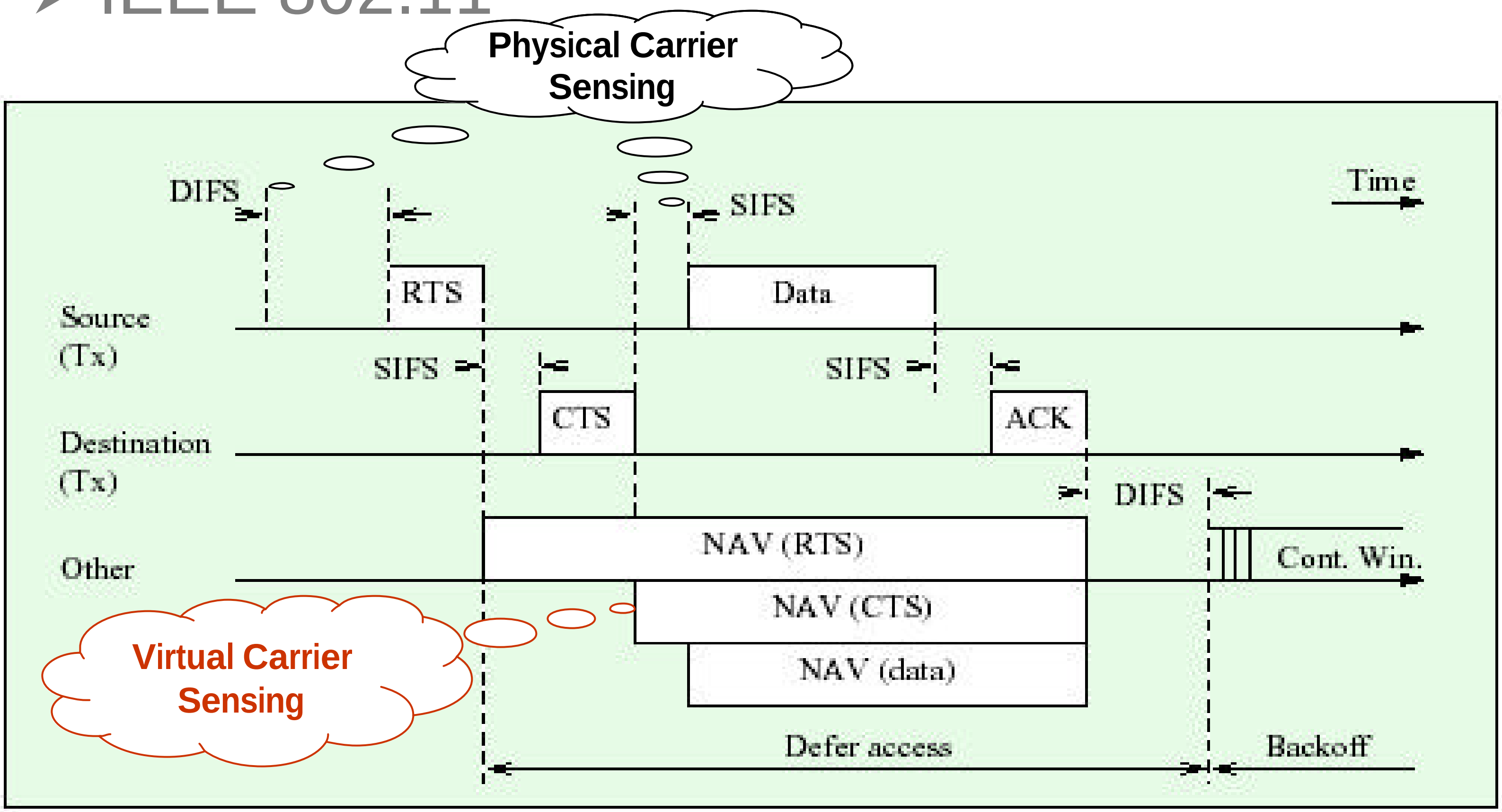
    Omni & Directional



- Omni Mode:
  - ✓ Omni Gain = Go
  - ✓ Idle node stays in Omni mode
- Directional Mode:
  - ✓ Capable of beamforming in specified direction
  - ✓ Directional Gain = Gd (Gd > Go)

Preliminaries(Cont.)

- IEEE 802.11



IEEE 802.11 DCF – RTS/CTS access scheme

Problem Formulation

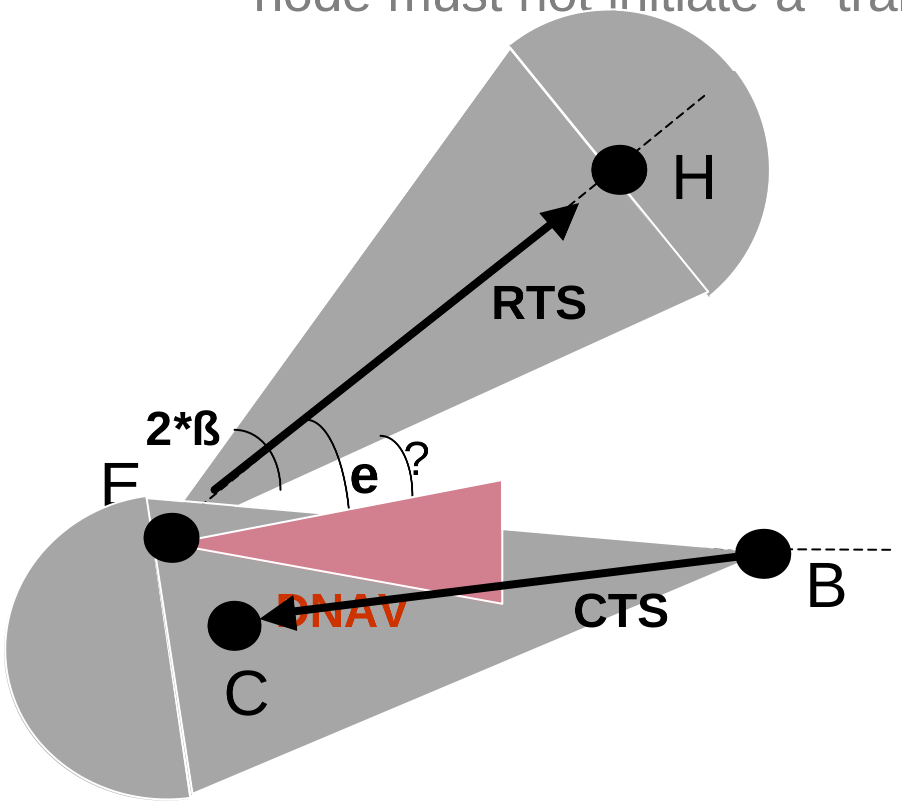
- Using directional antennas
  - ✓ Spatial reuse
    - ❖ Possible to carry out multiple simultaneous transmissions in the same neighborhood
  - ✓ Higher gain
    - ❖ Greater transmission range than omni-directional
    - ❖ Two distant nodes can communicate with a single hop
    - ❖ Routes with fewer hops

Basic DMAC Protocol

- Channel Reservation
  - ✓ A node listens omni-directionally when idle
    - Possible to carry out multiple simultaneous transmissions in the same neighborhood
  - ✓ Sender transmits Directional-RTS (DRTS) using specified transceiver profile
    - Physical carrier sense
    - Virtual carrier sense with Directional NAV
  - ✓ RTS received in Omni mode (only DO links used)
  - ✓ Receiver sends Directional-CTS (DCTS)
  - ✓ DATA,ACK transmitted and received directionally

Basic DMAC Protocol(Cont.)

- Directional NAV (DNAV) Table
  - ✓ Tables that keeps track of the directions towards which node must not initiate a transmission

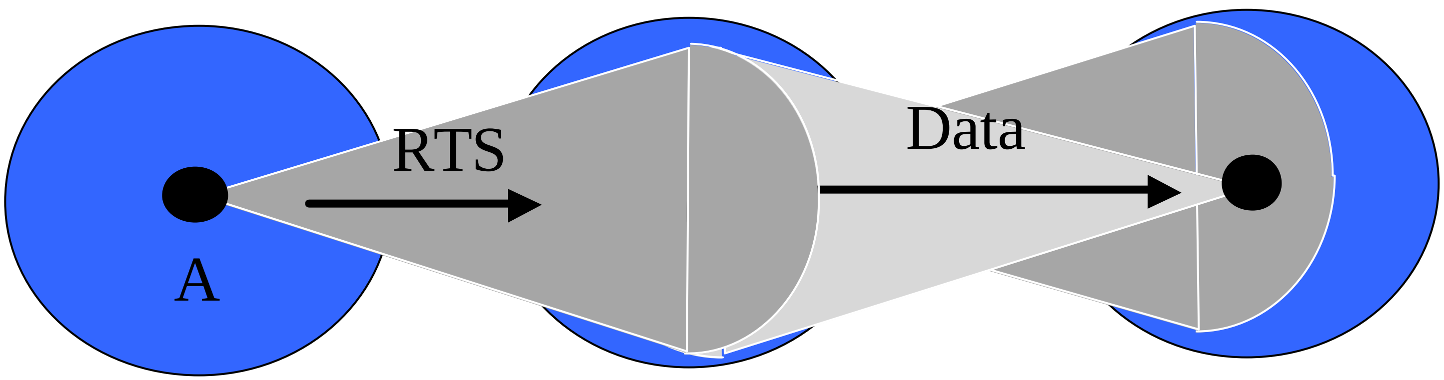


e = **2ß** + T

If T > 0 ,
New transmission can be initiated

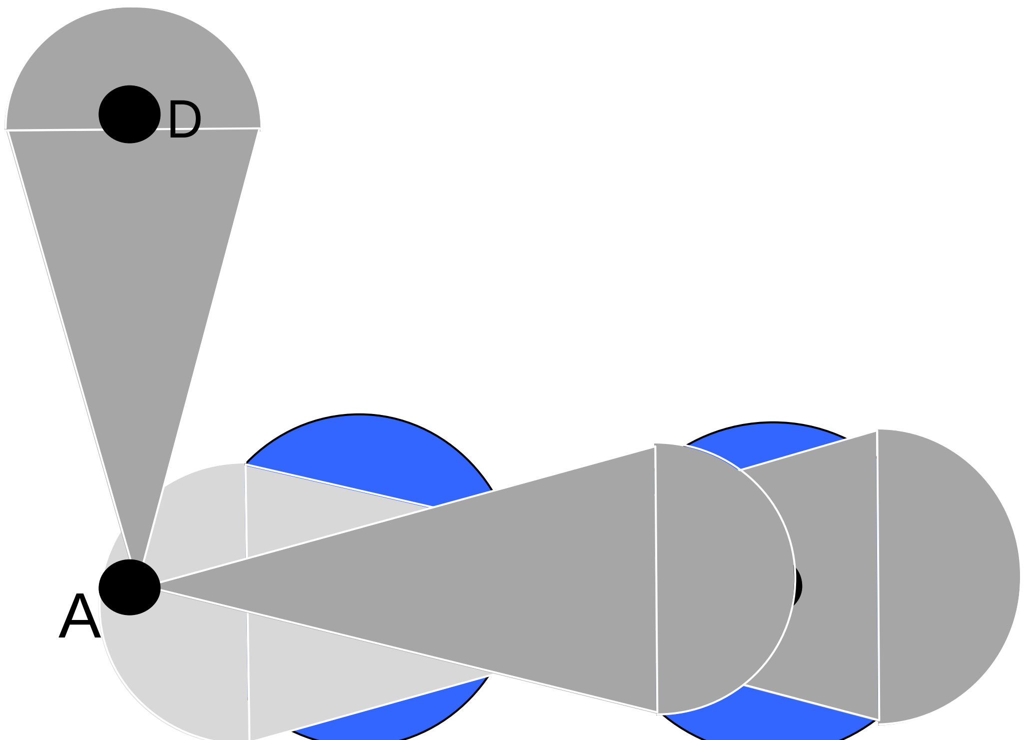
Problems with Basic DMAC

- Hidden Terminal Problems due to asymmetry in gain
  - ✓ A does not get RTS/CTS from C/B



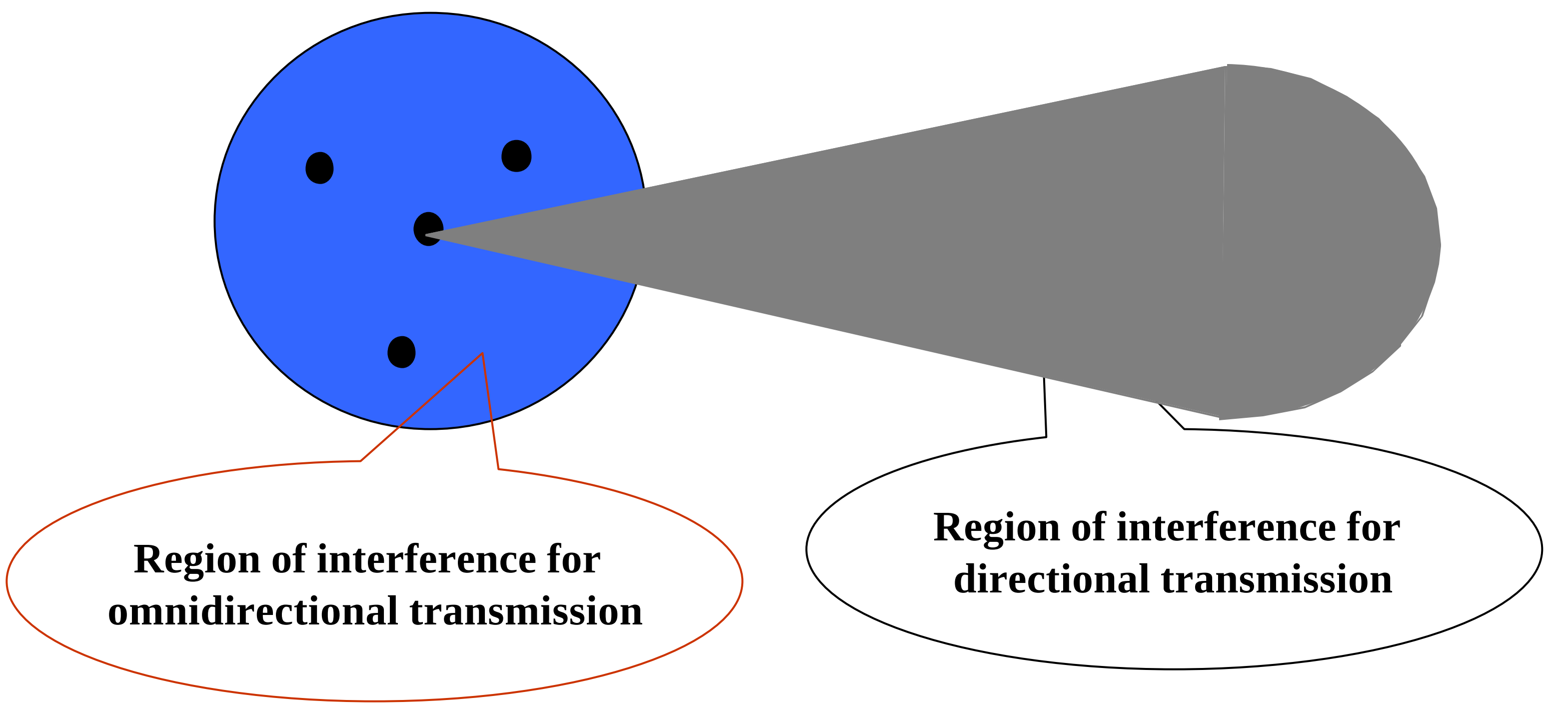
Problems with Basic DMAC(Cont.)

- Hidden Terminal Problems due to unheard RTS/CTS



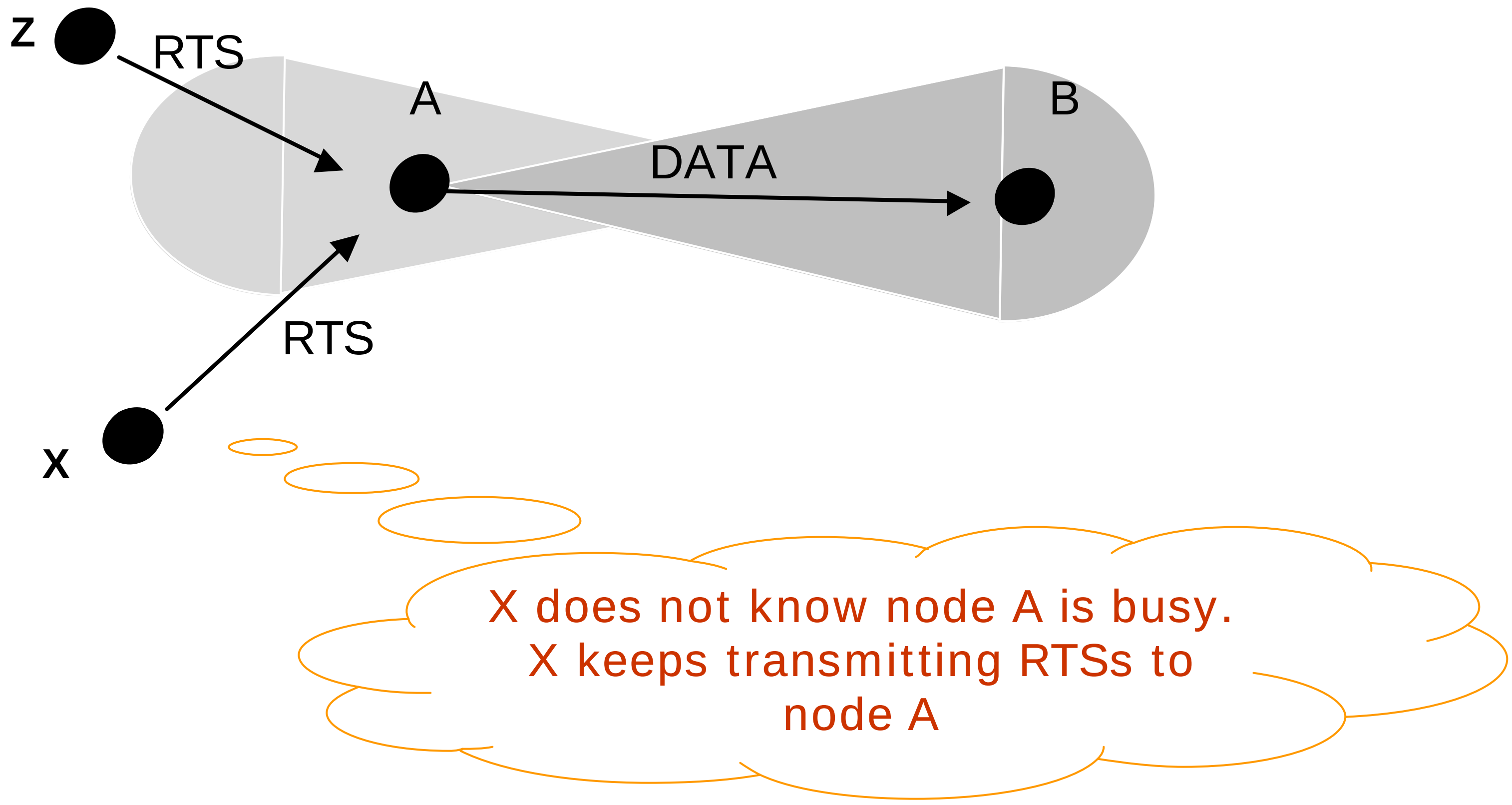
Problems with Basic DMAC(Cont.)

- Shape of Silence Regions



Problems with Basic DMAC(Cont.)

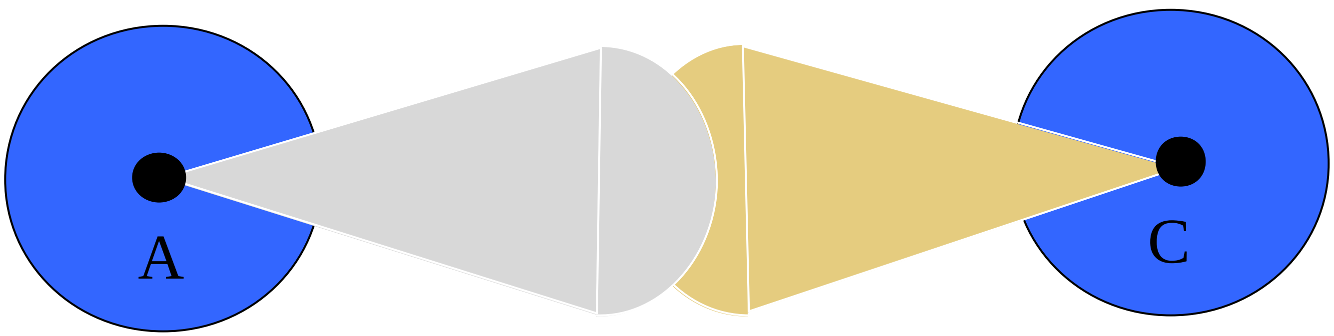
- Deafness



MMAC Protocol

- Attempts to exploit the extended transmission range
  - ✓ Make Use of DD Links

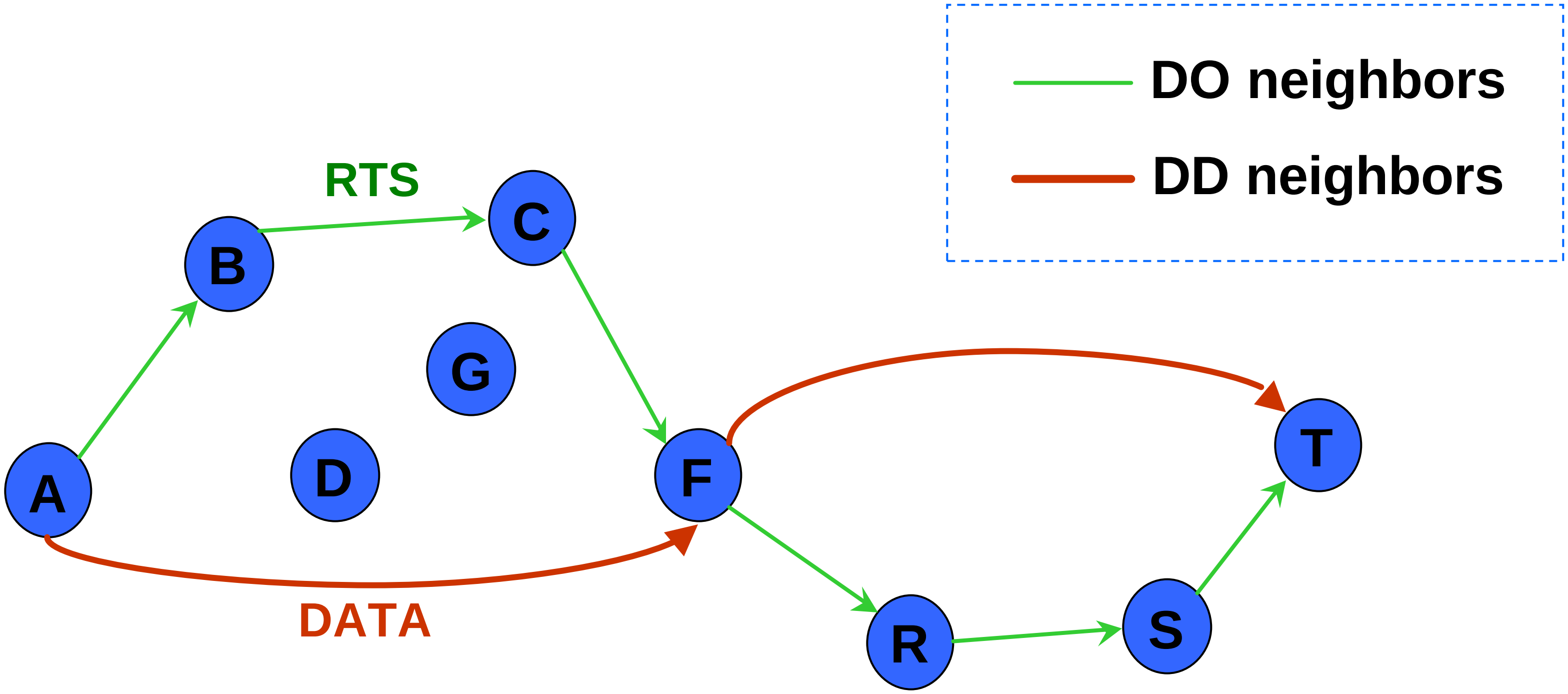
- Direction-Direction (DD) Neighbor



A and C can communication each other directly

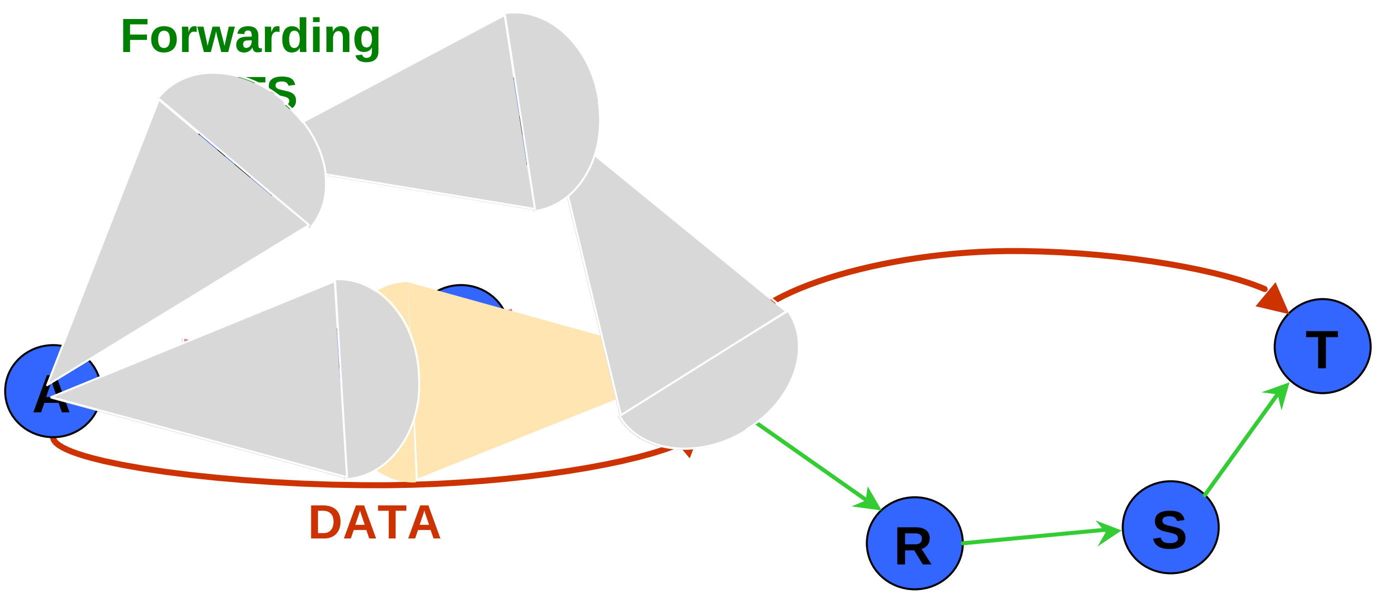
MMAC Protocol(Cont.)

- Protocol Description : Multi-Hop RTS
  - ✓ Based on Basic DMAC protocol



MMAC Protocol(Cont.)

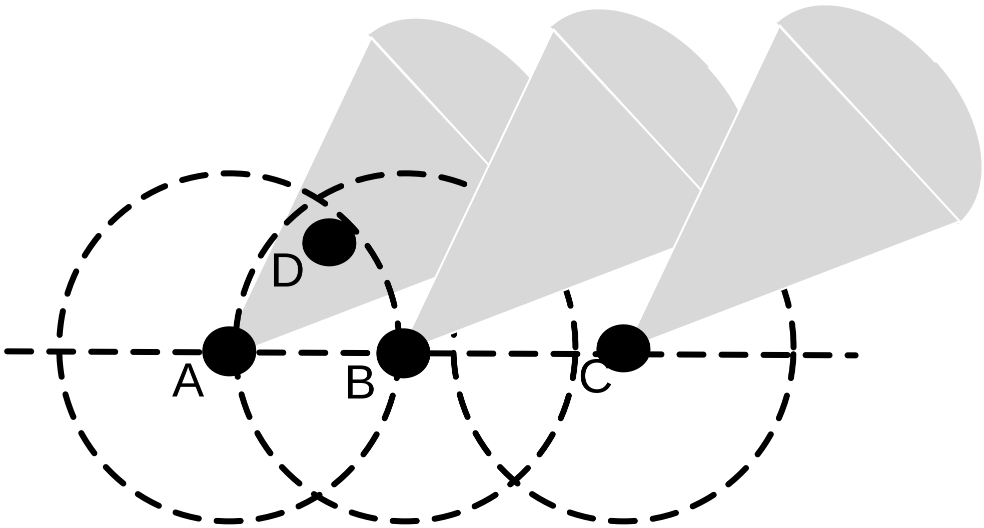
- Channel Reservation
  - ✓ Send Forwarding RTS with Profile of node F



Performance Evaluation

- Simulation Environment
  - ✓ Qualnet simulator 2.6.1
  - ✓ Beamwidth :45 degrees
  - ✓ Main-lobe Gain : 10 dBi
  - ✓ 802.11 transmission range : 250meters
  - ✓ DD transmission range : 900m approx
  - ✓ Two way propagation model
  - ✓ Mobility : none

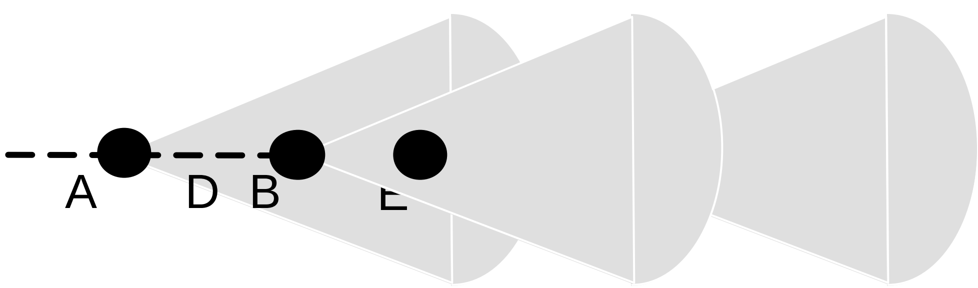
Performance Evaluation(Cont.)



High Spatial Reuse

Aggregate Throughput (Kbps)

IEEE 802.11 : 1189.73
Basic DMAC : 2704.18



High Directional Interference

Hidden terminal Problem

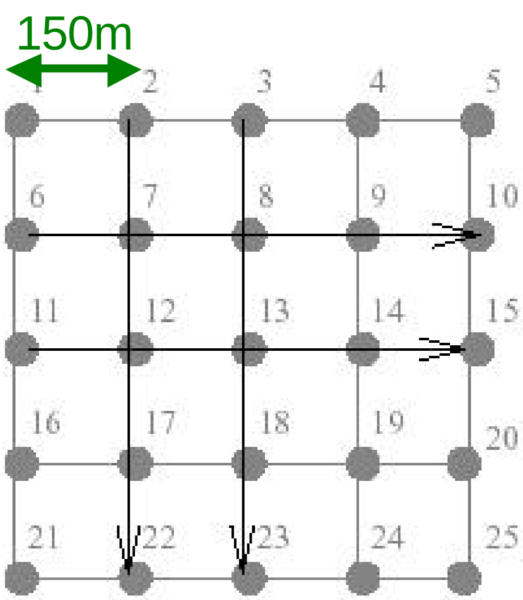
Aggregate Throughput (Kbps)

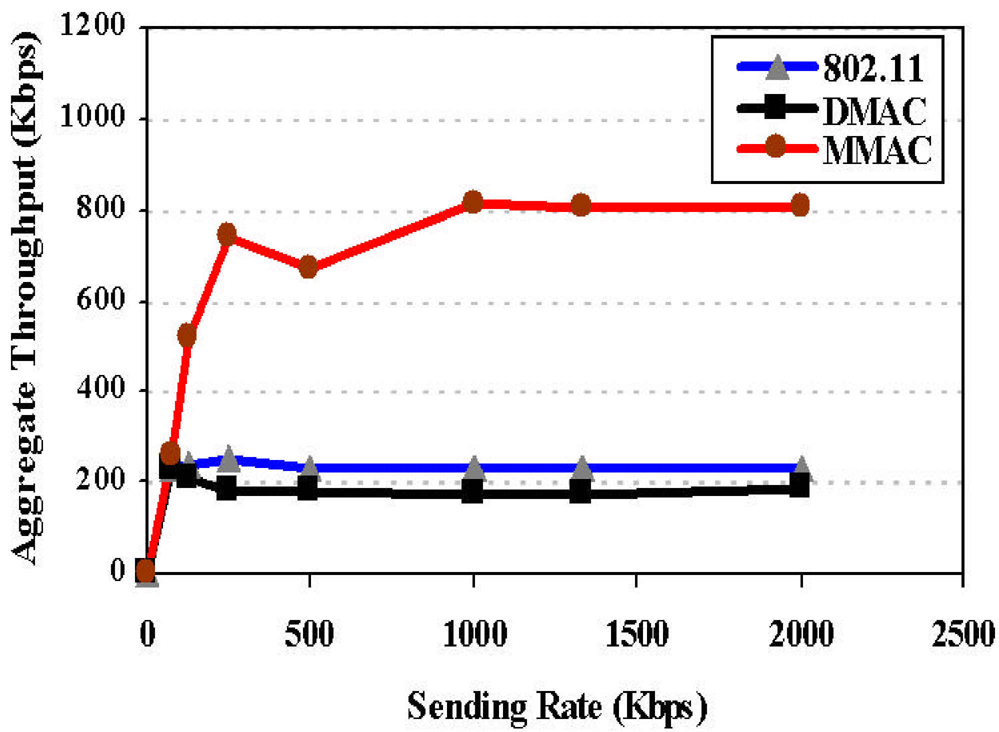
IEEE 802.11 : 1194.81
Basic DMAC : 1410.51

Using Directional Antennas for MAC in Ad Hoc Networks

Performance Evaluation(Cont.)

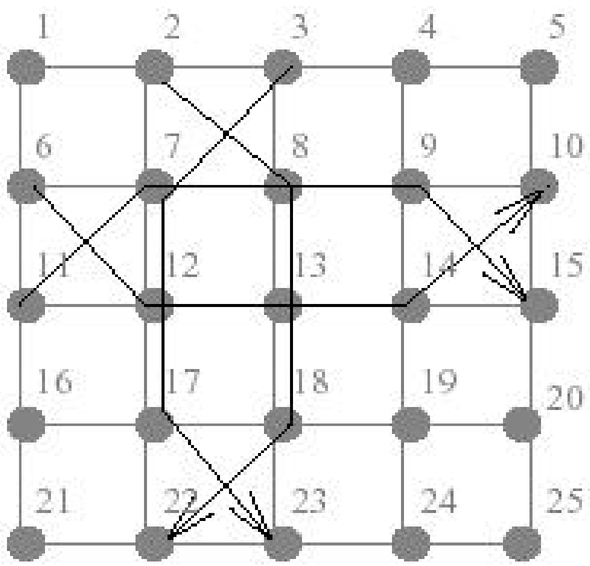
- Aligned Routes

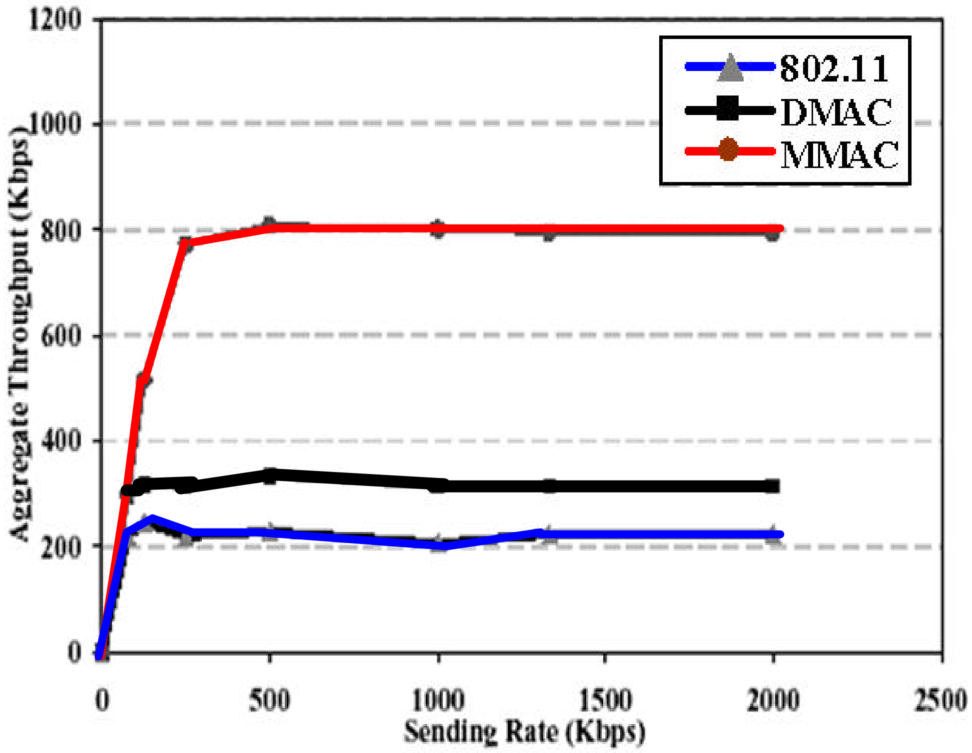




Performance Evaluation(Cont.)

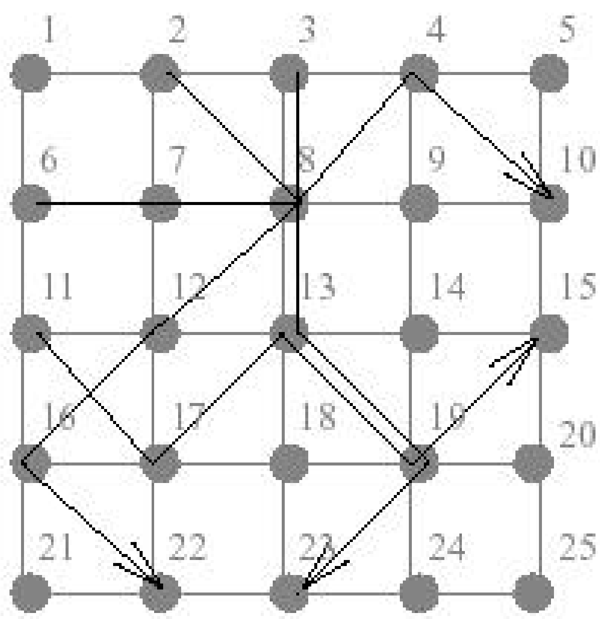
- Less aligned Routes

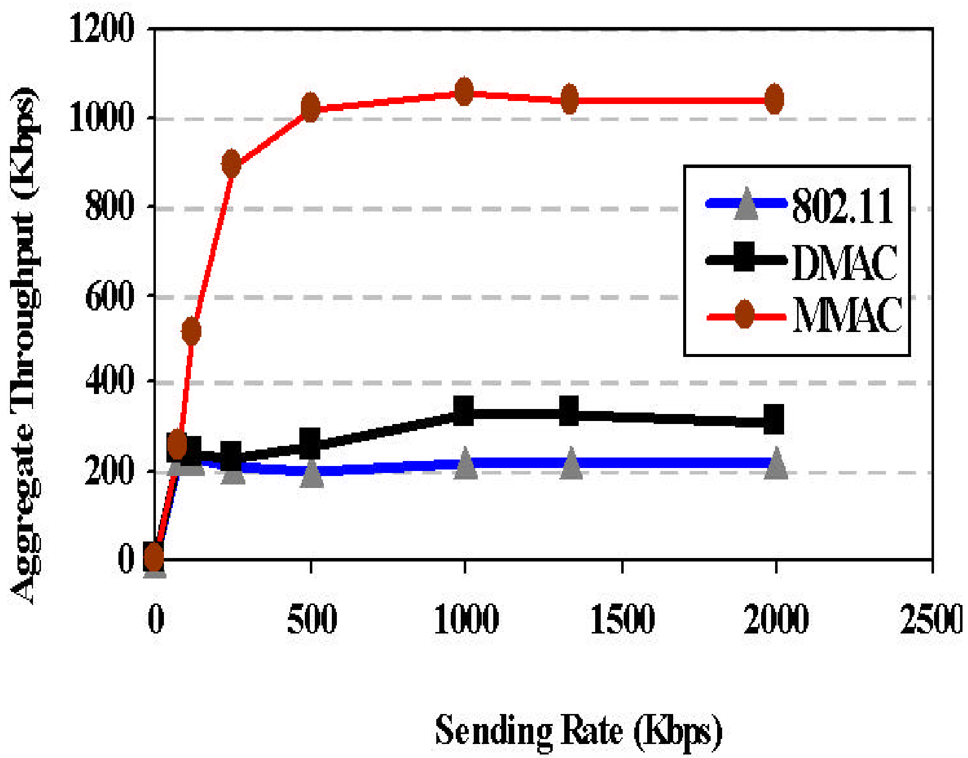




Performance Evaluation(Cont.)

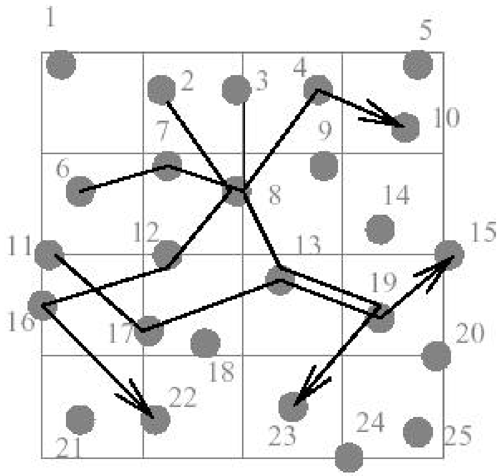
- Randomly Chosen Routes

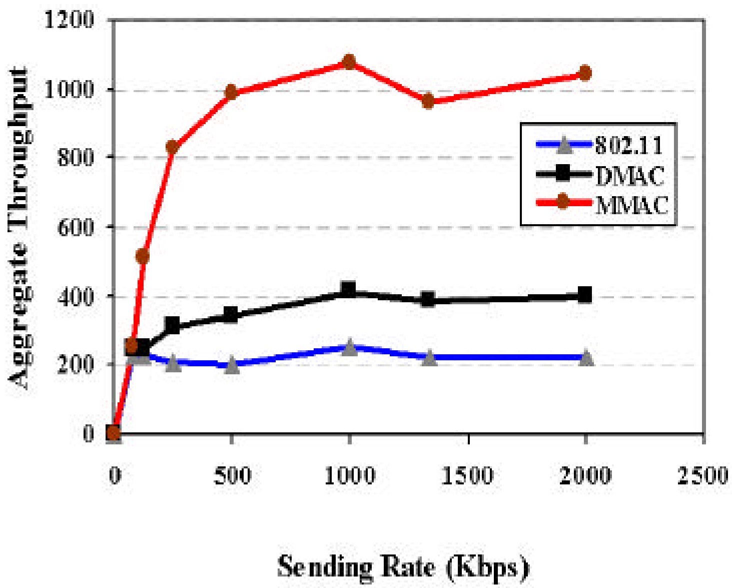


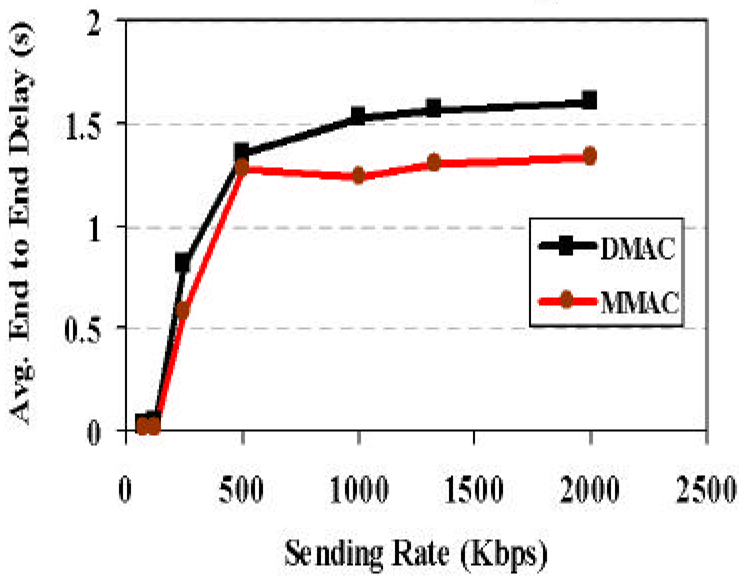


Performance Evaluation(Cont.)

- Random Topology







Future Work

- Design of directional MAC protocols that incorporate transmit power control
- New protocols that rely less on the upper layers for beamforming information
- Impact of directional antennas on the performance of routing protocol

Conclusion

- Directional MAC protocols show improvement in aggregate throughput and delay
  - ✓ But not always
- Performance dependent on topology
  - ✓ Random topology aids directional communication
- MMAC outperforms DMAC & 802.11
  - ✓ 802.11 better in some scenarios