Performance of Multi-Channel MAC Incorporating Opportunistic Cooperative Diversity

Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th
Sabbir Ahmed, Christian Ibars, Aitor del Coso and Abbas Mohammed

Presented by Yu-Chu Chang

31 Oct 2007

Outline

- Introduction
- Background
  - Cooperative diversity
  - Property of 802.11 networks
- CD-MMAC
- Simulation environment and results
- Conclusion

Introduction

- Recently cooperative communication has received a lot of attention due to its superior ability to combat fading caused by multi-path propagation.
- The basic idea of cooperative communication is to ask the partners to process the overheard information and forward it to the destination, which yields additional reliability of reception, or so-called cooperative diversity.

Introduction to cooperative diversity

- Figure 1 illustrates an example of the ideas of cooperative communications.

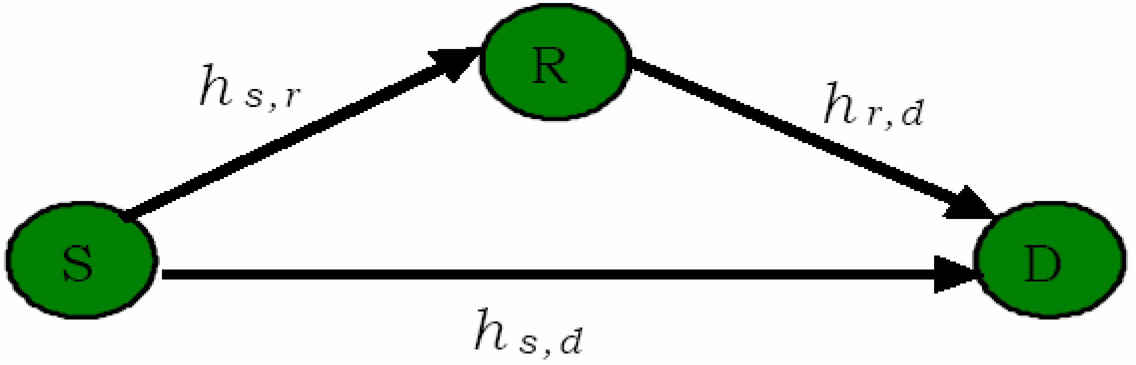


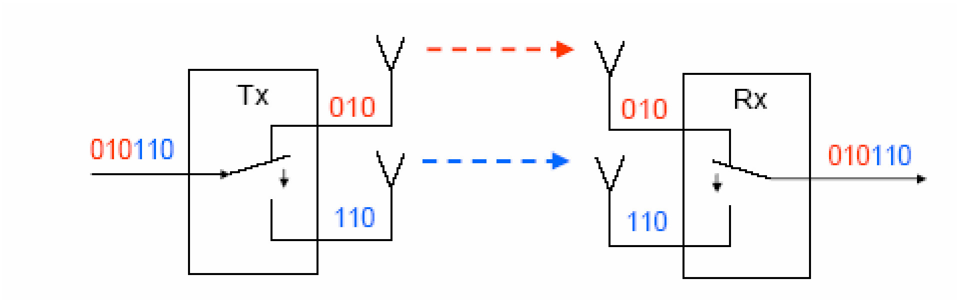
Figure 1: Cooperative Diversity Concept.

Introduction

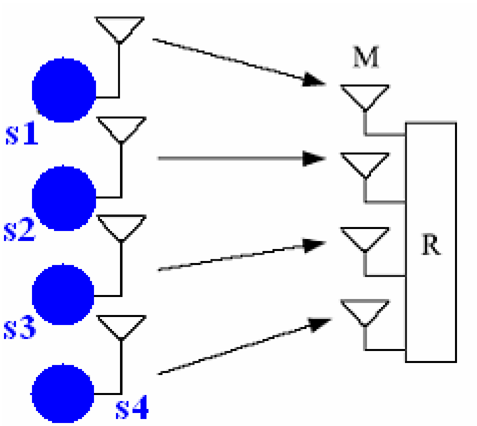
- Cooperative communication allows mobile nodes to exploit the benefits of MIMO systems;
- the mobile nodes in a multi-user environment can create a **virtual MIMO** system by sharing their antennas in order to achieve spatial diversity.

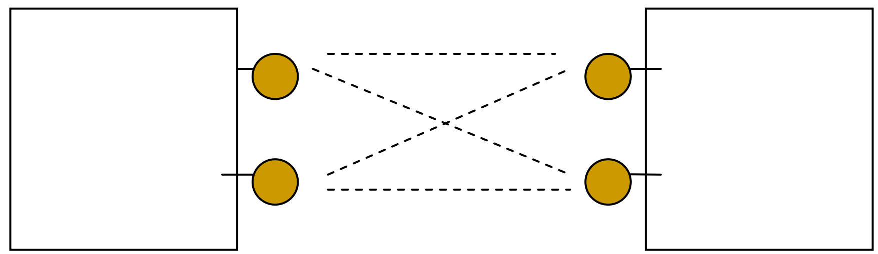
MIMO

- Multiple antennas
- Spatial diversity (reliability)
- Spatial multiplexing (data rates)
- Beamforming



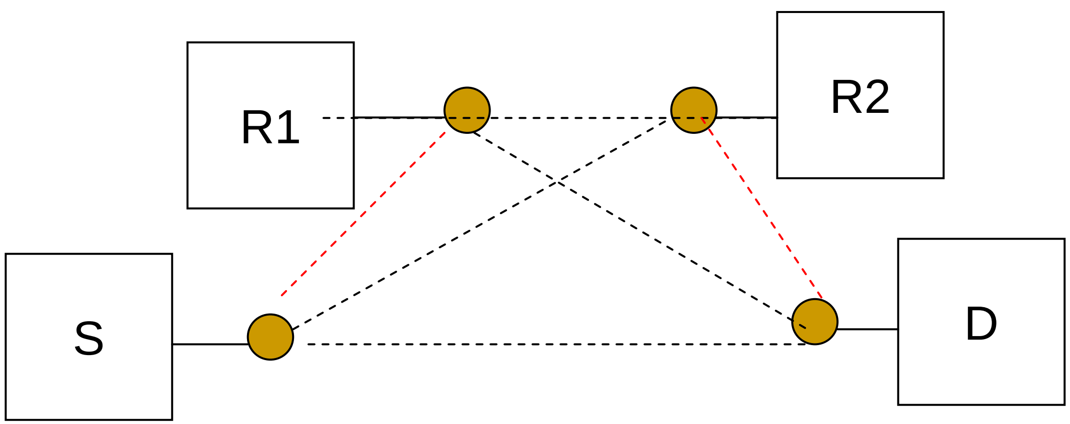
Virtual MIMO System





MIMO

Cooperation



Introduction

- This paper proposes a MAC protocol CD-MMAC (Cooperative Diversity Multi- Channel MAC) to improve the performance of wireless networks.
- The proposed protocol utilizes **multiple channels by using single interface** and incorporates **opportunistic cooperative diversity by using a cross-layer MAC**.
- The new protocol leverages the **multi-rate capability of IEEE 802.11b** and allows wireless nodes far away from destination node to transmit at a higher rate by using intermediate nodes as a relays.

Introduction

- Incorporating cooperative diversity at the MAC layer has explored two schemes:
  - pre-collision relayed scheme [4]
  - post-collision buffered scheme [5]

Property of 802.11b

- The IEEE 802.11b provides four different physical layer rates 1, 2, 5.5 and 11 Mbps using three different modulation schemes DBPSK, DQPSK and CCK.
- The most suitable modulation scheme can be chosen depending on the received SNR when quality of service parameter such bit error rate (BER) is given.

IEEE 802.11b DCF

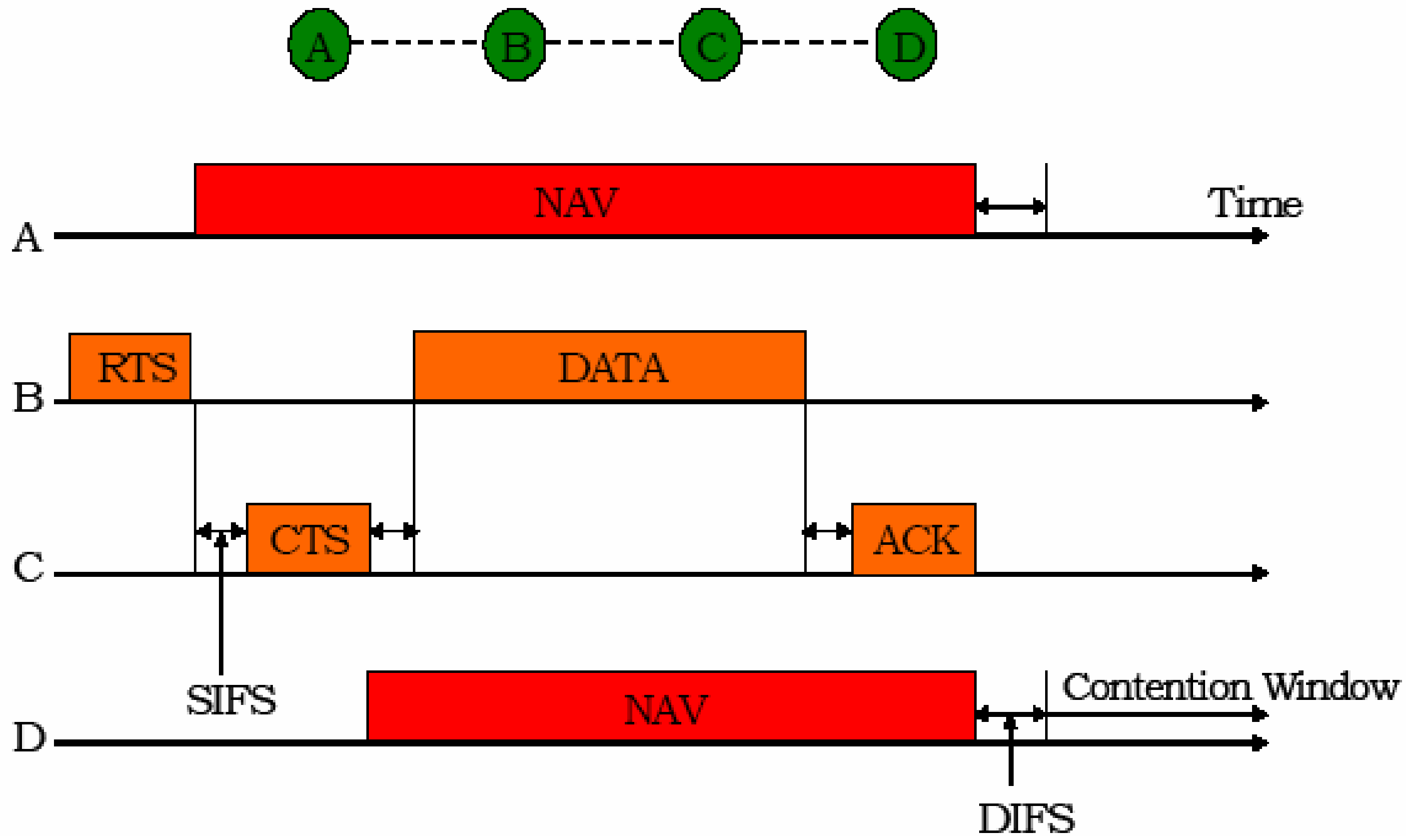


Figure 2: IEEE 802.11 DCF.

IEEE 802.11b PSM

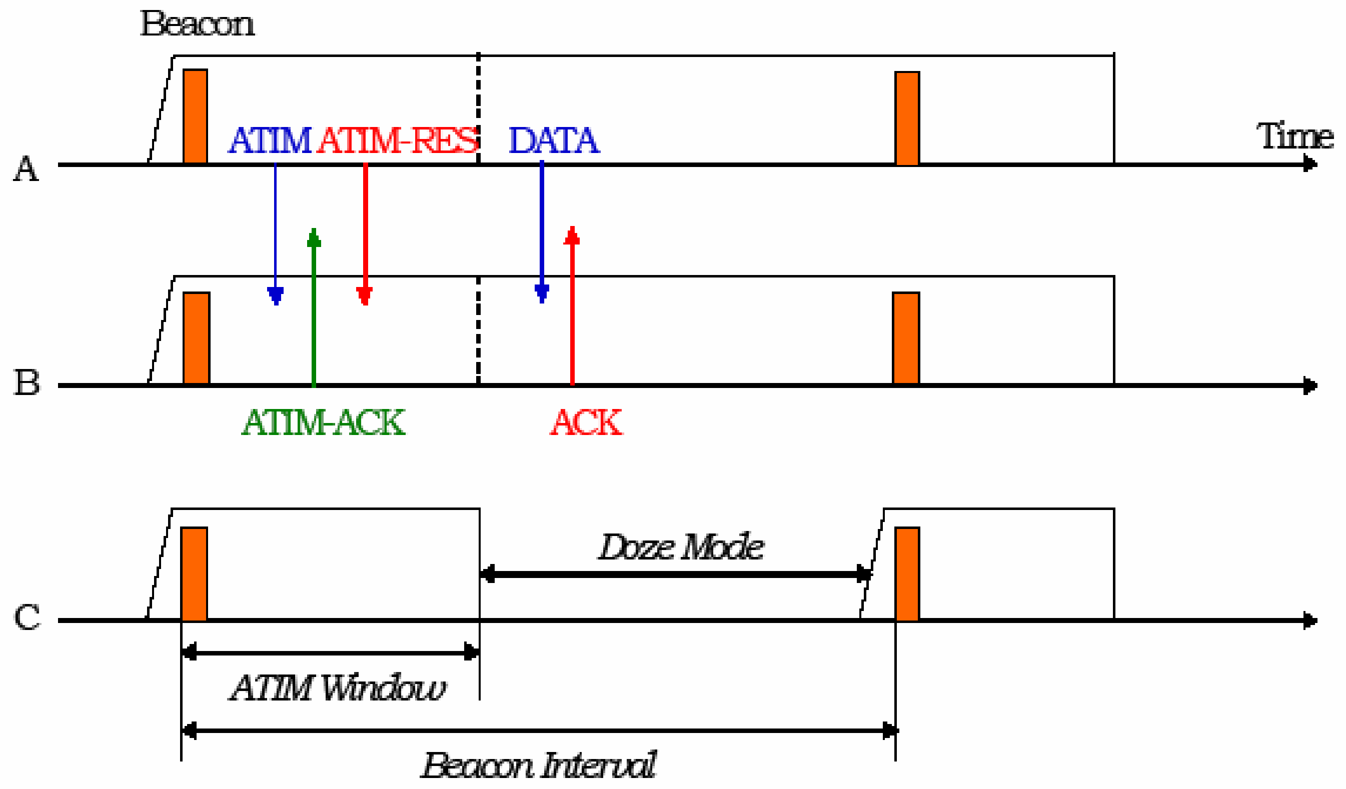


Figure 3: IEEE 802.11 PSM.

IEEE 802.11b Multi-Rate

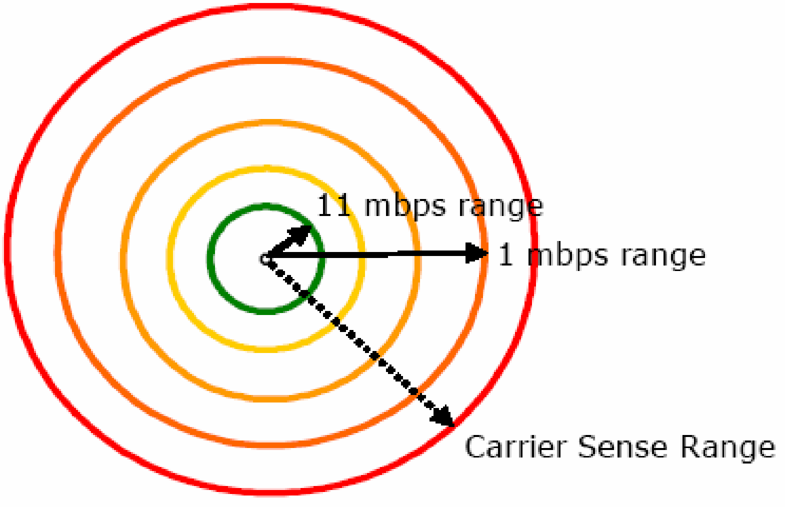


Figure 4: Transmission Range and Data Rate.

	Receive Threshold	Distance
Carrier Sense	-100dbm (1.00e-13 W)	1124 m
1 mbps	-94dbm (3.9811e-13 W)	796 m
2 mbps	-91dbm (7.9433e-13W	669 m
5.5 mbps	-87dbm (1.9953e-12 W)	532 m
11 mbps	-82dbm (6.3096e-12 W)	399 m

Table 1: Data Rate and Transmission Range.

Lucent ORiNOCO PC Card

CD-MMAC

- This paper incorporates opportunistic Cooperative Diversity by exploiting the Control Messages during the ATIM Window of MMAC.

Assumptions

- Three channels of same bandwidth are available for use and each node is equipped with a **single transceiver**.
- Transmission power of all nodes is fixed.
- Transmitting nodes choose the **best modulation scheme** based on the received signal-to-noise ratio (SNR)
- Nodes are synchronized so that all nodes begin their beacon interval at the same time.
- The transceiver is capable of switching channels and channel switching delay is approximately 1µs
- Nodes are synchronized so that all nodes begin their beacon interval at the same time.

Protocol Description

- This paper exploits the ATIM messages during the ATIM Window to build the **Node Rate Info Table**.
- Nodes build and update the Node Rate Info table listening to ATIM messages.
- In conventional routing nodes selects the minimum hop routes but here nodes select the best routes consulting the Node Rate Info table which is not always minimum hop.
- Nodes negotiate channels using ATIM messages. Nodes switch to selected channels after ATIM window for the rest of the beacon interval.

Node Rate Info

- Each node maintains a table of all possible relays around itself containing the ID (MAC Address), data rate (based on received SNR) and time (last heard from the relays).

Node Rate Info	
ID	Value
Data Rate	Value
Time	Value

Table 2: Data Structure Node Rate Information.

Preferable Channel List

- Each node also maintains a Table called PCL as in MMAC[7]. It records usage of channels inside the transmission range.
  - High preference (HIGH) – this channel has been already selected for the current beacon interval.
  - Medium preference (MID) – this channel has not been selected by other neighbor node.
  - Low preference (LOW) – this channel has been chosen by neighbor nodes.
- A counter is used for each channel in the PCL to record the planned usage of the channel for that interval of the source destination pair.

Channel Negotiation

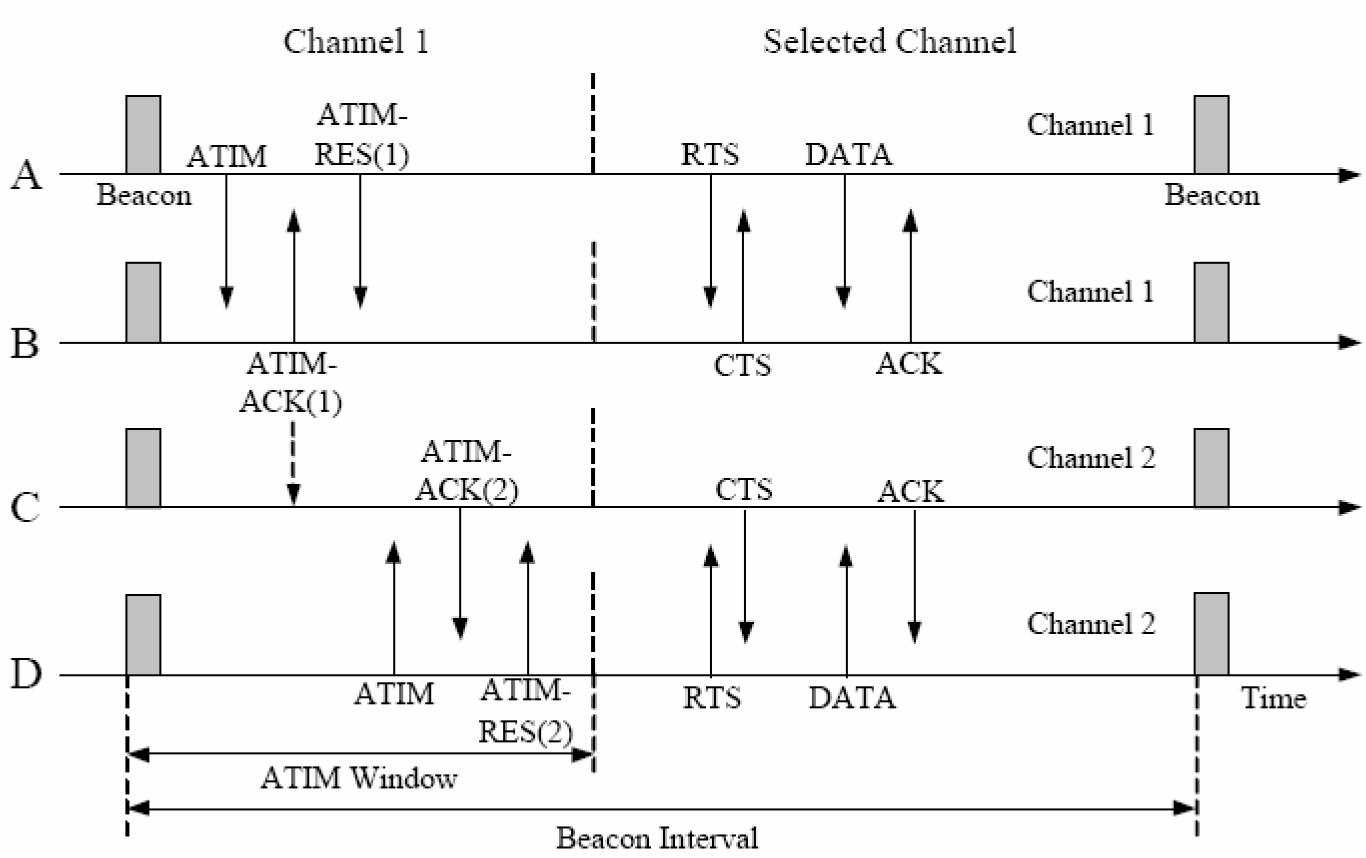


Figure 5: Channel Negotiation and Node Rate info exchange in CD-MMAC.

Simulation environment and results

- The Network Simulator NS-2 [10] has been used to simulate the proposed CD-MMAC protocol and to perform comparisons with 802.11b MMAC and CD-MMAC.

Simulation environment

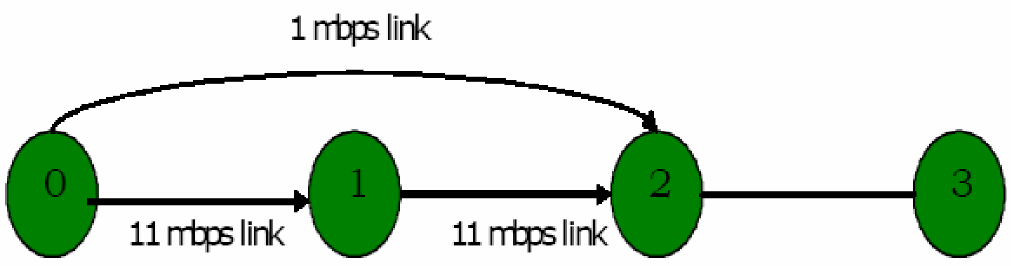


Figure 6: Chain Topology.

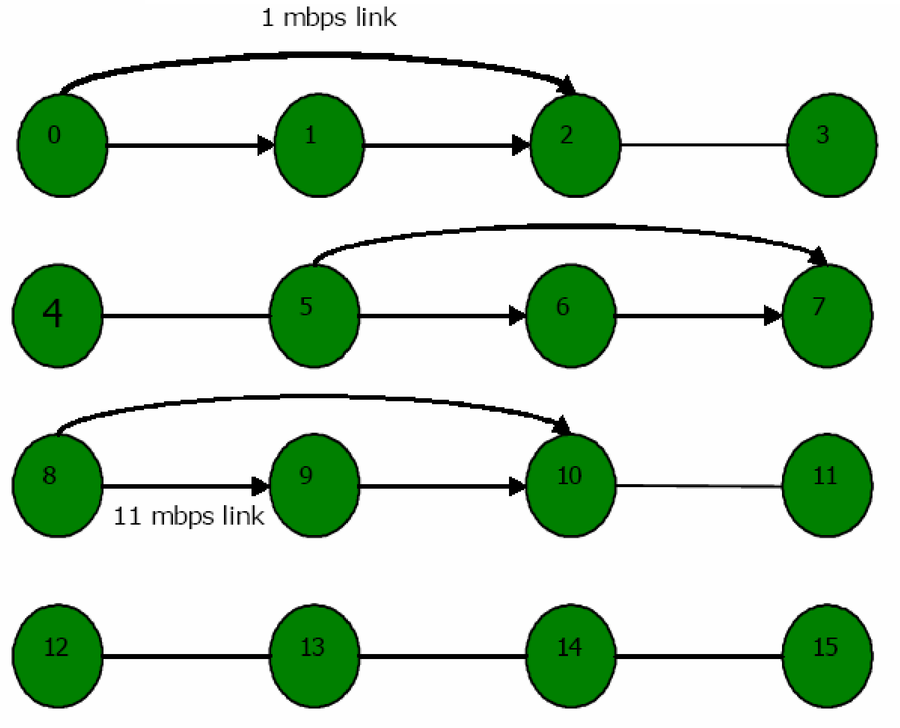


Figure 7: Grid Topology.

Simulation results

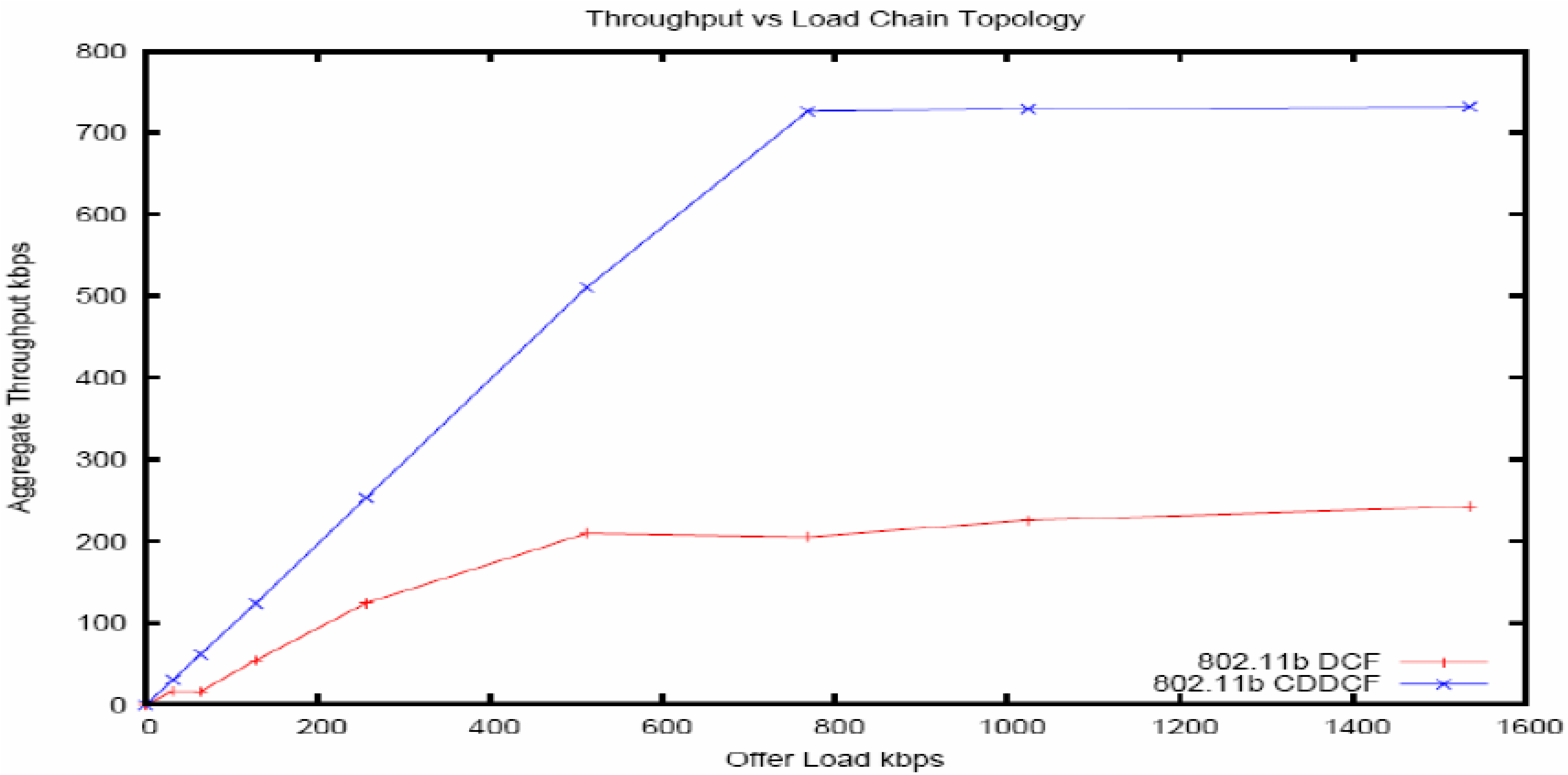


Figure 8: Load vs. Throughput Chain Topology.

Simulation results

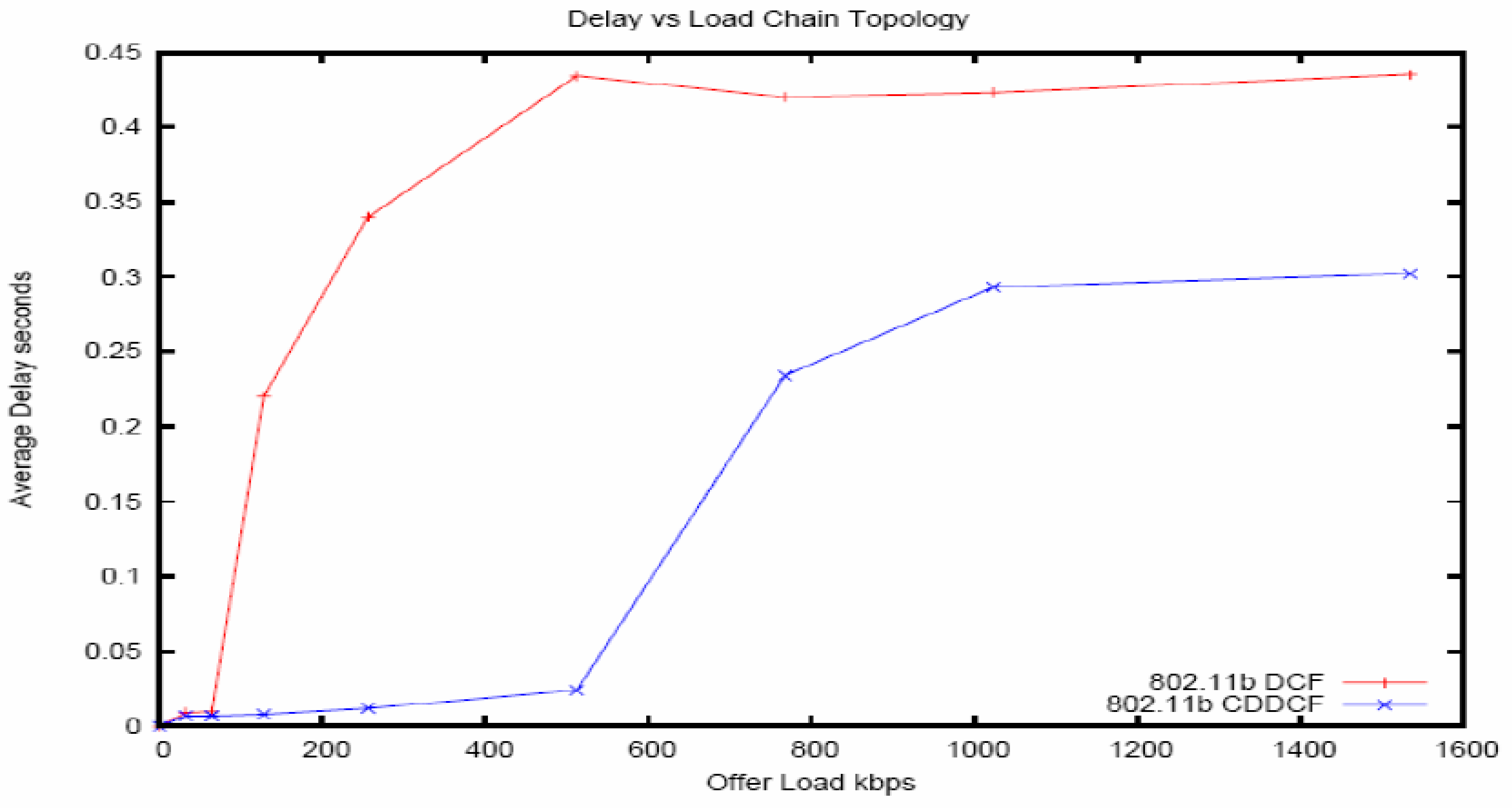


Figure 9: Load vs. Delay Chain Topology.

Simulation results

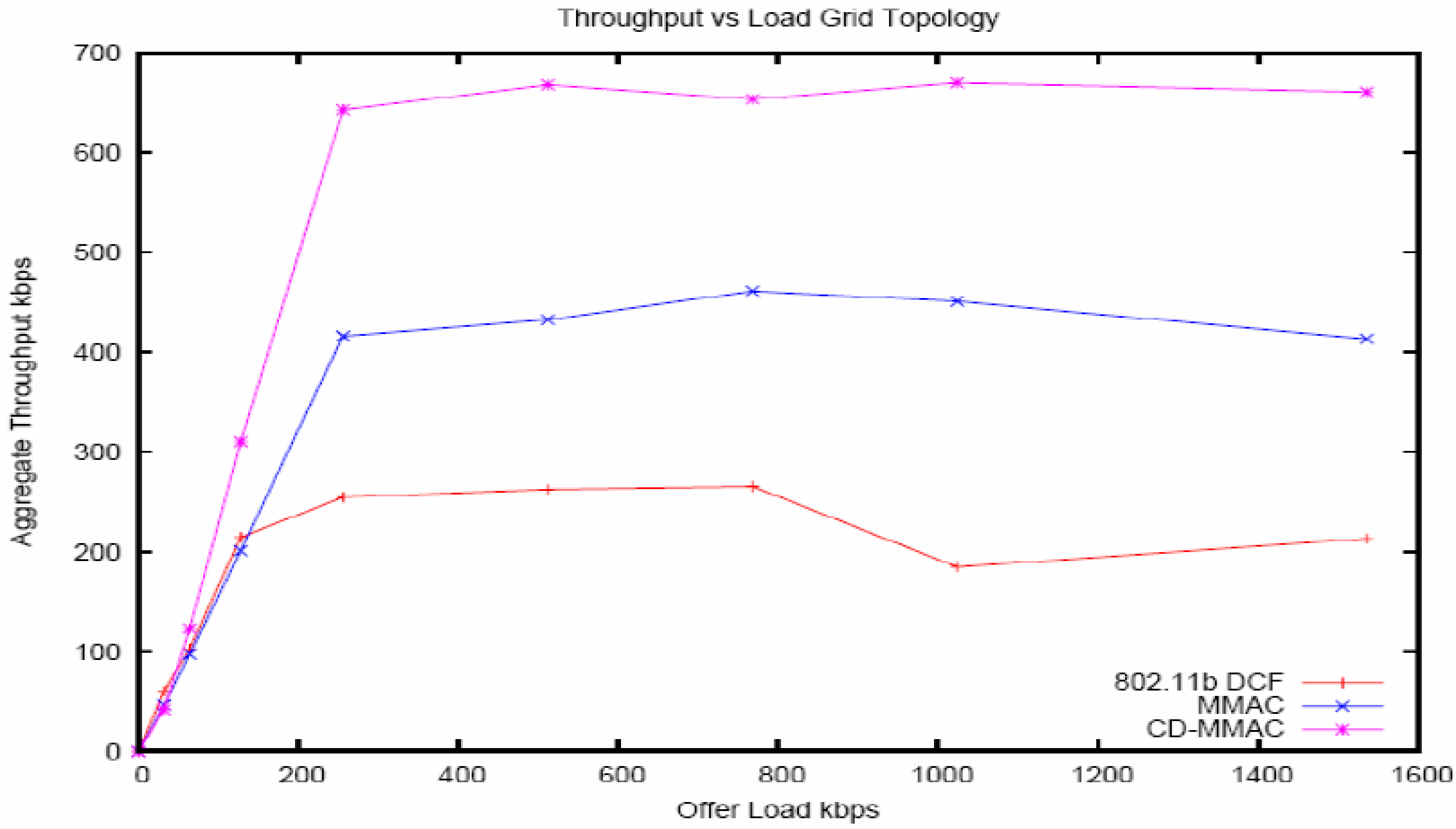


Figure 10: Load vs. Throughput Grid Topology.

Simulation results

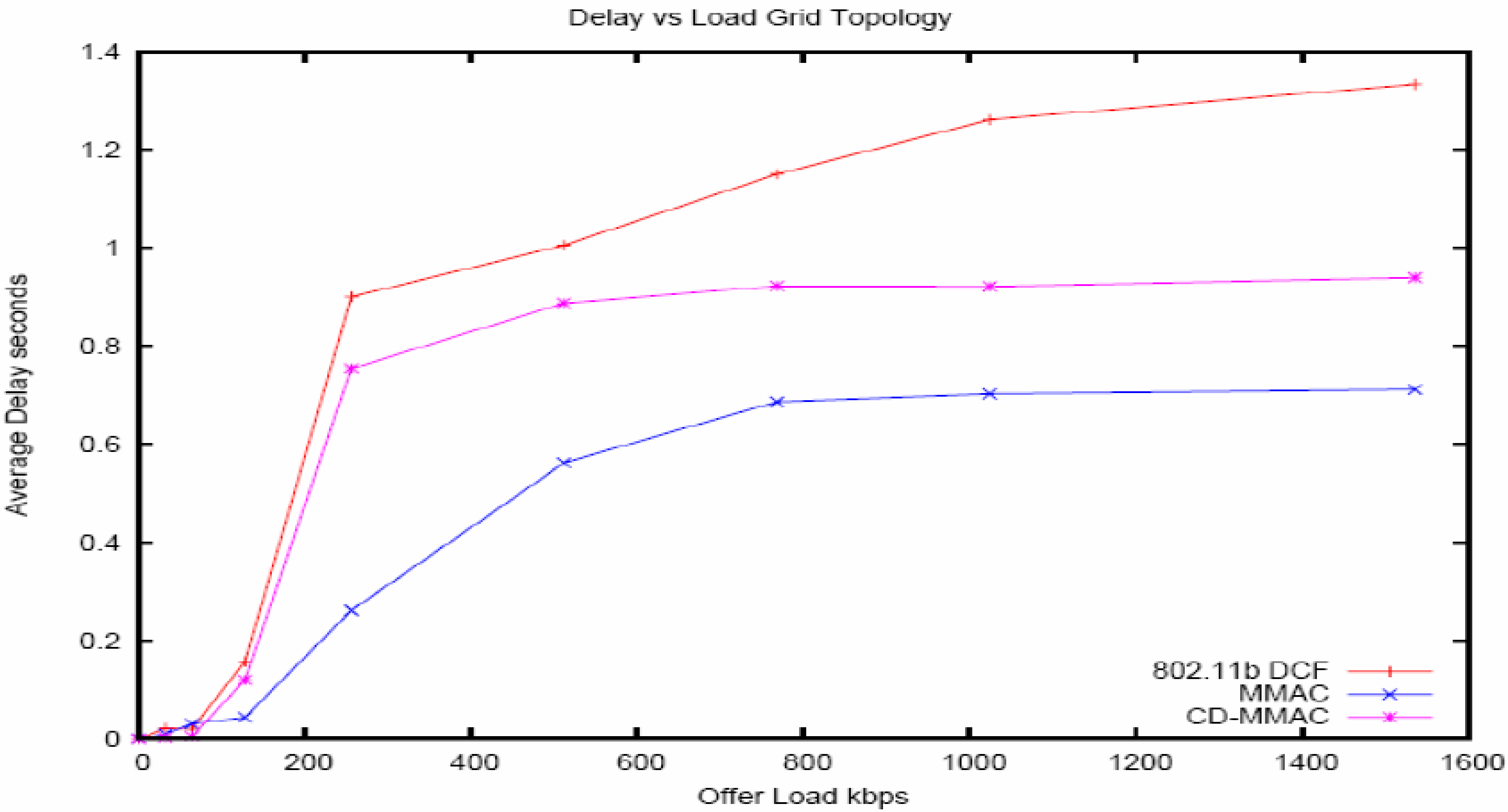


Figure 11: Load vs. Delay Grid Topology.

Conclusion

- This paper proposed a new MAC protocol CDMMAC for 802.11b Wireless Networks.
- The protocol utilizes multiple channels dynamically using a single interface and incorporates opportunistic cooperative diversity and makes better use of the multiple transmission rates offered by the physical layer.
- The simulation results show the protocol improves network throughput and packet delivery ratio significantly and reduces packet delay.