Brief Overview for Wireless Medium Access Control (MAC) Protocols

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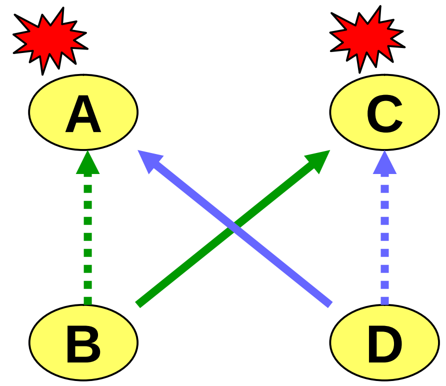
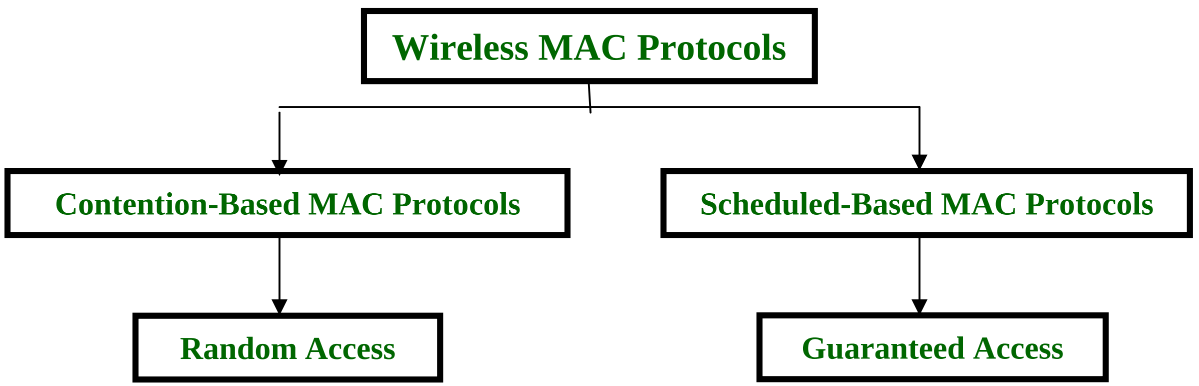
Overview for MAC Protocols

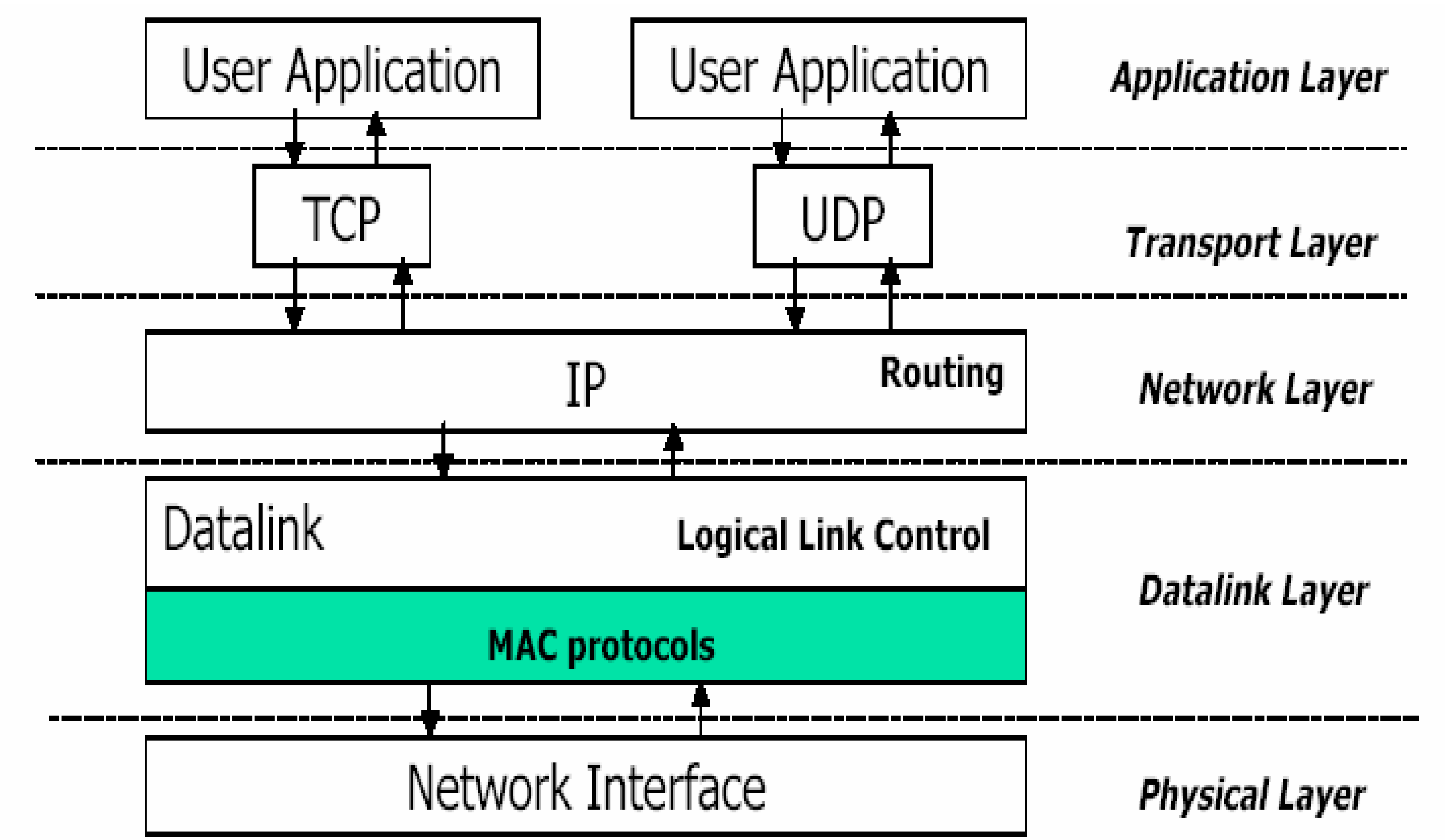
- Wireless medium is an open, shared, and broadcast medium
- Multiple nodes may access the medium at the same time



- Medium Access Control Protocol:
  - Define rules to force distributed nodes to access wireless medium in an orderly and efficiently manner
- Classification of Wireless MAC Protocols



Position of MAC within Protocol Stack

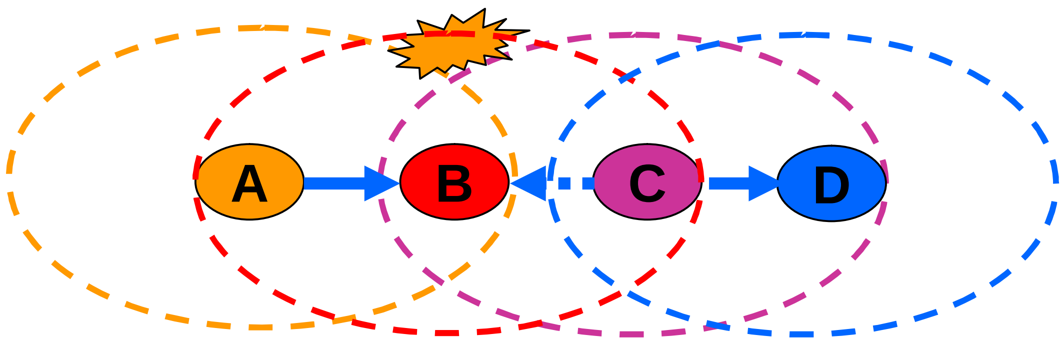


Wireless MAC Issues

- Half-Duplex Operation
- Time Varying Channel
- Burst Channel Errors
- Location Dependent Carrier Sensing
  - Hidden Terminal
  - Exposed Terminal
- Capture

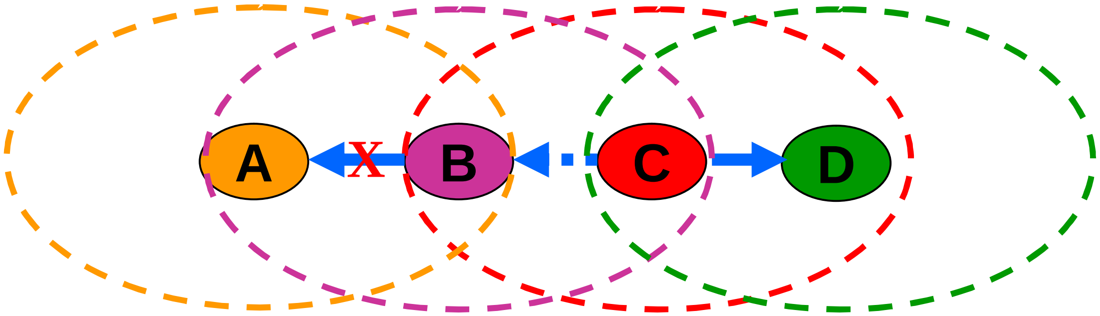
Hidden Terminal Problem

- Node B can communicate with A and C both
- A and C cannot hear each other
- When A transmits to B, C cannot detect the transmission using the *carrier sense* mechanism
- If C transmits to D, collision will occur at B

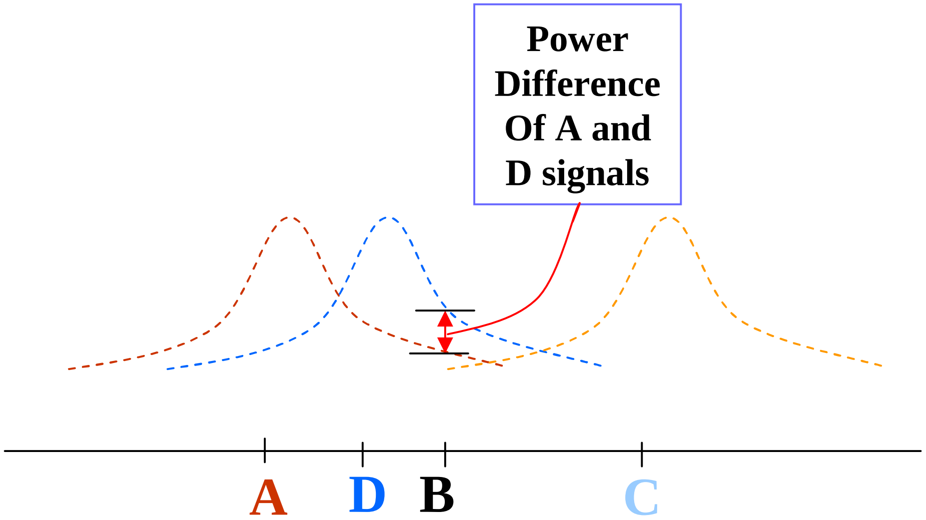


Exposed Terminal Problem

- Node C can communicate with B and D both
- Node B can communicate with A and C
- Node A cannot hear C
- Node D can not hear B
- When C transmits to D, B detect the transmission using the *carrier sense* mechanism and postpone to transmit to A, even though such transmission will not cause collision



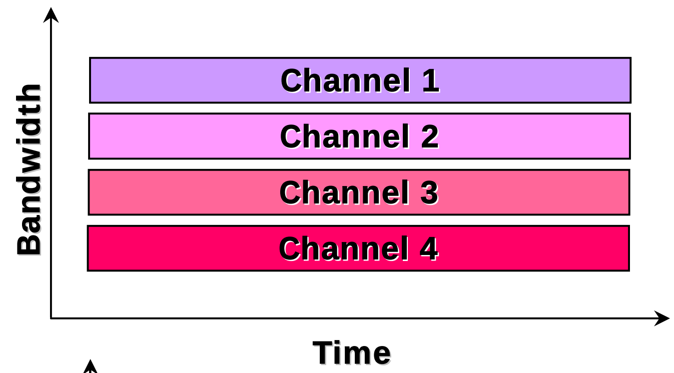
Capture Effect

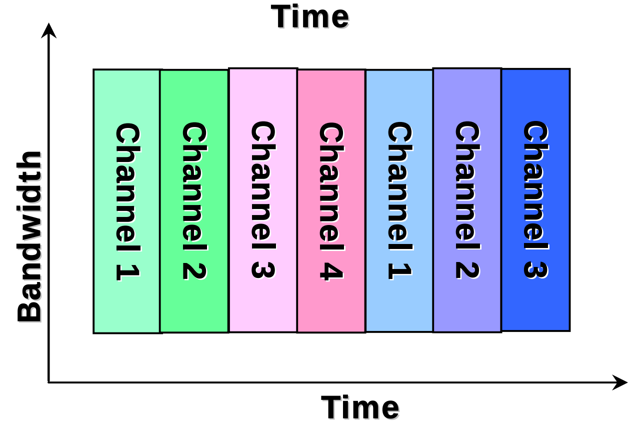


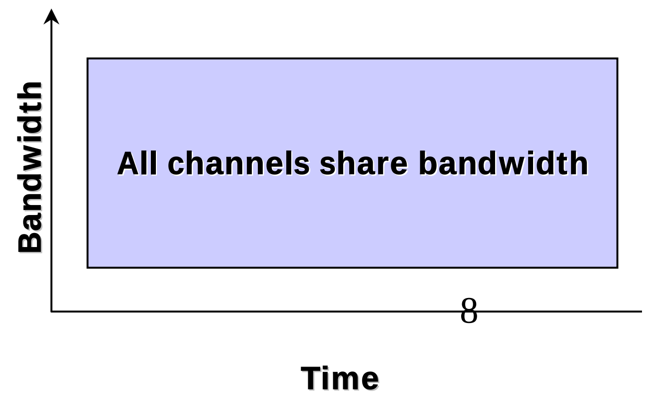
- A and D transmit simultaneously to B, the signal strength received by B from D is much higher than that from A, and D's transmission can be decoded without errors. This will result unfair sharing of bandwidth.

Scheduled-Based MAC Protocols

- Basic idea
  - to avoid collision and interference by scheduling nodes onto different sub-channels that are divided either by time, frequency, or orthogonal codes
- Examples:
  - FDMA
  - TDMA
  - CDMA
- Advantages:
  - Collision free
  - TDMA is very energy efficient and one of best choices for wireless sensor networks
- Disadvantages:
  - Not scalable
  - Low channel utilization
  - Need distributed, fine-grained time synchronization for TDMA







Contention-Based MAC Protocols

- Basic Goal:
  - Allow nodes to compete for a shared channel and make protocol simple, flexible, and scalable
- Key mechanism: collision avoidance
  - Collision avoidance with out-of-band signaling
  - Collision avoidance with in-band control messages
- Several popular contention-based MAC protocols
  - ALOHA
  - CSMA
  - DFWMAC: Distributed Foundation Wireless MAC (used in IEEE 802.11)
  - EY-NPMA: Elimination Yield-Nonpreemptive Priority Multiple Access (used in HyperLan)
- Advantages:
  - Scalable
  - Easy to implement
  - Flexible
- Disadvantages:
  - Collision is a major problem
  - Inefficient usage of energy

Ideal MAC Protocol

- Limited Delay
- High Throughput
- Fairness
- Stability
- Scalability
- Robustness against channel fading
- Low power consumption
- Support for multimedia

Main Major Sources Of Energy Waste

- Collisions
- Overhearing
- Control Overhead
- Idle Listening

Examples for Idle, Receiving, and Transmitting Energy Cost

Radio State	Power Consumption (mW)
Transmit	81
Receive	30
Idle Listening	30
Sleep	0.003

Table 1. Characteristics of a sensor radio [7].

Table 1: The power modes of two different cards operated at 11 Mbps.

Chipset	Sleep (mW)	Idle (mW)	Receive (mW)	Transmit (mW)
ORiNOCO PC Gold	60	805	950	1400
Cisco AIR-PCM350	45	1080	1300	1875

Two New MAC Protocol Survey Papers

- "A Survey, Classification and Comparative Analysis of Medium Access Control Protocols For Ad-Hoc Netwoks", R. Jurdak, C. V. Lopes, and P. Balda, in IEEE Comunications Survey and Tutorials, 6(1), 2004
- "Energy Efficent Medium Access Control", K. Langendoen and G. Halkes, Technical Report in Delft University of Technology, June 2004

Protocol	Published	Channel	Topology	Trans. initiation	Power efficient	Traffic load and scalability	Range
1. CSMA [4]	1975	Single	Single/Flat	Sender	No	Wired networks	Medium
2. BTMA [5]	1975	1 control/1 data	Centralized	Sender	No	Hidden terminal	Long
3. PRMA [6]	1988	Hybrid	Centralized	Sender	No	Voice	V. short
4. MACA [7]	1990	Single	Single/Flat	Sender	No	Hidden terminal	N/A
5. MACAW [8]	1994	Single	Centralized	Sender	No	Delivery guarantee	Medium
6. FAMA [9]	1995	Single	Single/Flat	Sender	No	Delivery guarantee	Medium
7. IEEE 802.11 [1]	1996	Multiple (FHSS/DSSS)	Single/Flat	Sender	No	Access point	Medium
8. HIPERLAN [2]	1996	Multiple (hybrid)	Clustered	Sender	Yes	Data relay	Short
9. MACA-BI [10]	1997	Single	Multiple/Flat	Receiver	No	Predictable traffic	Long
10. FPRP [11]	1998	Multiple (time)	Multiple/Flat	Sender	No	Voice	N/A
11. PAMAS [12]	1998	1 control/1 data	Multiple/Flat	Sender	Yes	Dense low load	Medium
12. Bluetooth [3]	1999	Multiple (FHSS)	Clustered	Master	Yes	Low rate PAN	V. short
13. Markowski [13]	1999	Multiple (time)	Single/Flat	N/A	Yes	Voice	N/A
14. HRMA [14]	1999	Hybrid	Multiple/Flat	Sender	No	Large packets	N/A
15. MCSMA [15]	1999	Multiple (frequency)	Single/Flat	Sender	No	High density	Medium
16. PS-DCC [16]	1999	Single	Single/Flat	Sender	Yes	High load	Medium
17. RIMA-SP [17]	1999	Single	Single/Flat	Receiver	No	Predictable traffic	N/A
18. ADAPT [18]	1999	Multiple (time)	Multiple/Flat	Sender	No	High load	Medium
19. CATA [19]	1999	Multiple (time)	Multiple/Flat	Sender	No	Low load	Medium
20. Jin [20]	2000	Hybrid	Clustered	Sender	Yes	Heterogenous	N/A
21. MARCH [21]	2000	Single	Multiple/Flat	Sender	Implicit	Homogeneous	V. short
22. RICH-DP [22]	2000	Multiple (FHSS)	Multiple/Flat	Receiver	No	High load	Long
23. SRMA/PA [23]	2000	Multiple (time)	Multiple/Flat	Sender	Yes	Voice	N/A
24. DCA-PC [24]	2001	1 control/N data	Multiple/Flat	Sender	Yes	High density	Short
25. GPC [25]	2001	Single	Clustered	N/A	Yes	High density	N/A
26. VBS [26]	2001	N/A	Clustered	N/A	No	Voice	N/A
27. DPC/ALP [27]	2002	Single	Multiple/Flat	Sender	Yes	Heterogenous	Long
28. Lal [28]	2002	Multiple (space)	Multiple/Flat	Receiver	Implicit	High load/Density	Medium
29. GRID-B [29]	2002	1 control/N data	Multiple/Flat	Sender	No	High load/Density	Medium
30. MC MAC [30]	2002	Multiple (CDMA)	Multiple/Flat	Sender	No	High rate PAN	V. short
31. WCA [31]	2002	N/A	Clustered	N/A	Yes	Heterogeneous	N/A
32. DBTMA [32]	2002	2 control/1 data	Multiple/Flat	Sender	No	Hidden terminal	Short
33. MMAC [33]	2002	Multiple (space)	Multiple/Flat	Sender	Yes	High load	Medium
34. D-PRMA [34]	2002	Multiple (time)	Single/Flat	Sender	No	Voice	Medium

Table 1. *Chronological protocol classification.*

RMAC: A Reliable Multicast MAC Protocol for Wireless Ad Hoc Networks

Weisheng Si and Chengzhi Li

Proceedings of IEEE ICPP 2004, August 2004.

Four Papers for Our Class

- "MACA - A New Channel Access Method for Packet Radio", in the proceedings of the 9th ARRL Computer Networking Conference, London, Ontario, Canada, 1990.
- " MACAW: A Media Access Protocol for Wireless LANs'', V. Bharghavan, A. Demers, S. Shenker, and L. Zhang, *ACM Sigcomm '94,* London, UK.
- "Dual busy tone multiple access (DBTMA): A multiple access control scheme for ad hoc networks", J. Deng and Z. Haas, in IEEE Trans. on Communications, vol. 50, no. 6, 2002
- "Cross-Layer Scheduling for Power Efficiency in Wireless Sensor Networks", M. L. Sichitiu, IEEE INFOCOM 2004