The Abdus Salam
International Centre for Theoretical Physics

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First Workshop on Open Source and Internet Technology for Scientific Environment: with case studies from Environmental Monitoring

7 - 25 September 2009

Introduction to Networking

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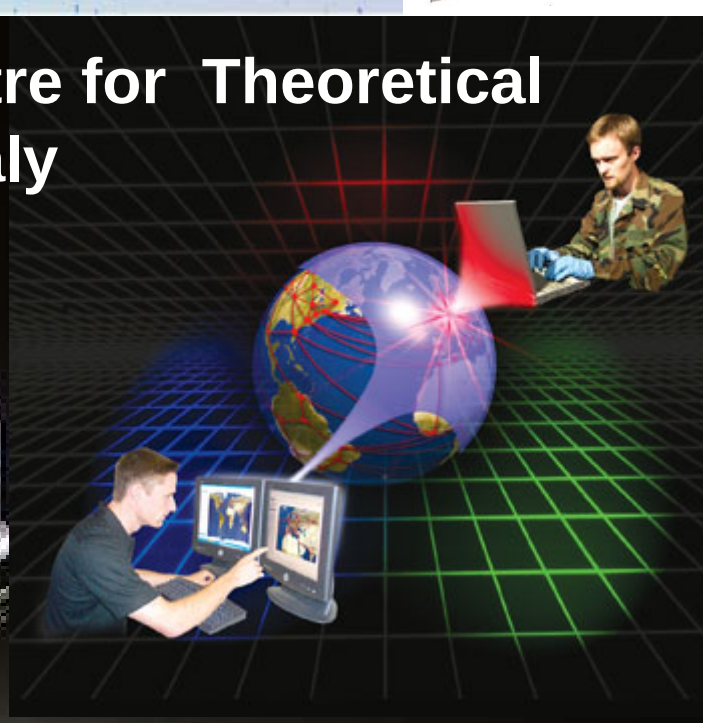
"Scientific thought is the common heritage of mankind" – Abdus Salam

25 YEARS OF MICROPROCESSOR TRAINING
1981 - 2006

The Abdus Salam International Centre for Theoretical Physics, Trieste, Italy



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Introduction to Computer Networks

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Introduction to Networks

- How much do you know about networks?

Introduction to Networks

- 4 lectures
  - Overview of Network Architectures, Protocols
  - TCP/IP Internals
  - Useful protocols in TCP/IP stack
    - DHCP
    - tftp
    - NFS
    - Using Wireshark (originally *Ethereal*)
  - Introduction to Wireless Sensor Networks

Paradigm Shifts
since early 1950s

Type	Description	Communication Technology	Transmission Technology
Terminal Networks	Connect “dumb” terminals to a central computer	WAN – PSTN 56 – 64 Kbps	Copper cable
Data Networks	Connect networks to networks	WAN – PSDN 56 Kbps – 10 Gbps	Coax cable Wireless •Radio, Satellite, µWave OF
Local Area Networks	Connect computer resources spread in a small area	LAN 1 Mbps – 10 Gbps	Coax cable •Thick wire •Thin wire •UTP, STP, OF •WiFi

Paradigm Shifts
since early 1950s

Type	Description	Communication Technology	Transmission Technology
Metropolitan Area Networks	Connect resources spread in a city	MAN 100 Mbps – 10 Gbps	Coax Cable OF, WiMAX, µWave
Personal Area Networks	Connect resources localised in a small area	PAN 100 Kbps -	UTP, WiFi, Bluetooth, IrDA
Wireless Personal Area Networks	Connect resources localised in a small area using short range wireless	WPAN	RFID, IrDA, Bluetooth, ZigBee

Paradigm Shifts
since early 1950s

Type	Description	Communication Technology	Transmission Technology
Master Slave	Terminal Networks	WAN (PSTN)	Coax Cable
Distributed – Client Server	Enterprise computing. Connect resources belonging to one organisation	WAN (PSDN) , LAN, MAN, PAN, WSN	UTP, WiFi, Bluetooth, IrDA
Distributed – Grid Computing	Connect resources distributed across the globe. Also P2P	WAN, LAN, PAN, WSN, WPAN	OF, Satellite, UTP, WiFi, RFID, IrDA, Bluetooth, ZigBee
Cloud Computing	Extra thin clients connect to resources concentrated in a few places.	WAN, LAN, PAN, WSN, WPAN	OF, Satellite, UTP, WiFi, RFID, IrDA, Bluetooth, ZigBee

Networking Standards

- Why do we need standards?
- Standard making bodies:
  - ISO
  - IEEE
  - ANSI
  - IETF
  - National Standard Bodies
  - SIGs/Forums/Alliances

Reference Models

- ISO – OSI (Open System Interconnect)

7 Layer Reference Model			
	Unit	Layer	Function
User/Host Layers	Data	7 - Application	Application to Network Process and vice-versa
		6 – Presentation	Data representation & encryption
		5 – Session	Interhost communication
	Segment	4 – Transport	End-to-end connection
Network Operator /Media Layers	Packet	3 – Network	Network routing
	Frame	2 – Data Link	Physical Link
	Bit	1 – Physical	Physical Media

Reference Models

IEFT TCP/IP Reference Model (3 + 1 layers)			
Unit	Layer	Function	Protocol(s)
Data	3 - Application	Application to Network Process and vice-versa	Many
Segment	2 – Transport	End-to-end connection Reliability and Flow Control	TCP or UDP
Packet	1 – Network	Network routing	IP
Frame/Bit	0 – Host to network	Link control and bit transfer	Many

Reference Models

TCP/IP – 5 Layer Reference Model

Unit	Layer	Function	Protocol(s)	Standard body
Data	5 - Application	Application to Network Process and vice-versa	Many	IETF
Segment	4 – Transport	End-to-end connection Reliability and Flow Control	TCP or UDP	IETF
Packet	3 – Network	Network routing	IP	IETF
Frame	2 – Data Link	Logical Link Control (LLC) Media Access Control (MAC)	Ethernet + others	IEEE + other forums
Bit	1 – Physical Media	Bits on wire	Many	ANSI, ISO

LAN/MAN Standards

LAN

MAN

Logical Link Control (LLC) Layer
IEEE 802.2

MAC Layer

CSMA/CD
IEEE 802.3

Token Bus
IEEE 802.4

Token Ring
IEEE 802.5

FDDI
IEEE 802.6

WLAN – CSMA/CA
IEEE 802.11
a/b/g/n

WPAN
IEEE 802.15

WMAN
IEEE 802.16

54 Mbps
5 GHz

11 Mbps
2.4 GHz

54 Mbps
2.4 GHz

600 Mbps
2.4/5 GHz

LAN/MAN Standards

LAN

MAN

Logical Link Control (LLC) Layer
IEEE 802.2

MAC Layer

CSMA/CD
IEEE 802.3

Token Bus
IEEE 802.4

Token Ring
IEEE 802.5

FDDI
IEEE 802.6

WLAN
CSMA/CA
IEEE 802.11
a/b/g/n

WPAN
IEEE 802.15

WMAN
IEEE 802.16

Bluetooth
IEEE 802.15.1

High Bit Rate
(11/22/33/44/55 Mbps
IEEE 802.15.3

ZigBee Alliance
LBR CSMA/CA
IEEE 802.15.4

LAN/MAN Standards

LAN

MAN

Logical Link Control (LLC) Layer
IEEE 802.2

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IEEE 802.6

WLAN
IEEE 802.11
a/b/g/n

WPAN
IEEE 802.15

WMAN
IEEE 802.16

WiMAX FORUM®

LAN/MAN Standards

LAN

MAN

Logical Link Control (LLC) Layer
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CSMA/CD
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FDDI
IEEE 802.6

WLAN
IEEE 802.11
a/b/g/n

WPAN
IEEE 802.15

WMAN
IEEE 802.16

MBWA
IEEE 802.20

The ZigBee Protocol

- The ZigBee protocol carries all the benefits of the 802.15.4 protocol with added networking functionality.
- The ZigBee protocol was engineered by the ZigBee Alliance, a non-profit consortium of leading semiconductor manufacturers, technology providers, OEMs and end-users worldwide.
- The protocol was designed to provide OEMs and integrators with an easy-to-use wireless data solution characterized by low-power consumption, support for multiple network structures and secure connections.
- The ZigBee protocol was designed to carry data through the hostile RF environments that routinely exist in commercial and industrial applications.

ZigBee protocol features

- Low duty cycle - Provides long battery life
- Low latency
- Support for multiple network topologies: Static, dynamic, star and mesh
- Up to 65,000 nodes on a network
- 128-bit AES encryption – Provides secure connections between devices
- Collision avoidance
- Link quality indication
- Clear channel assessment
- Retries and acknowledgements
- Support for guaranteed time slots and packet freshness

Comparison of three technologies

Standard	ZigBee IEEE802.15.4	WiFi IEEE802.11b	Bluetooth IEEE802.15.1
Range (m)	100	100	10
Battery life (days)	100 – 1000	0.5 – 5.0	1 – 7
No of nodes	> 64,000	32	7
Application	Monitoring & Control	Web, Email, Video	Cable Replacement
Throughput (Kb/s)	20 – 250	11,000	720

LAN/MAN/WPAN Standards

- Mostly IEEE standards
- Bluetooth SIG
- WiFi forum - certification
- WiMAX forum - certification
- SIGs and forums supplement the work of the IEEE

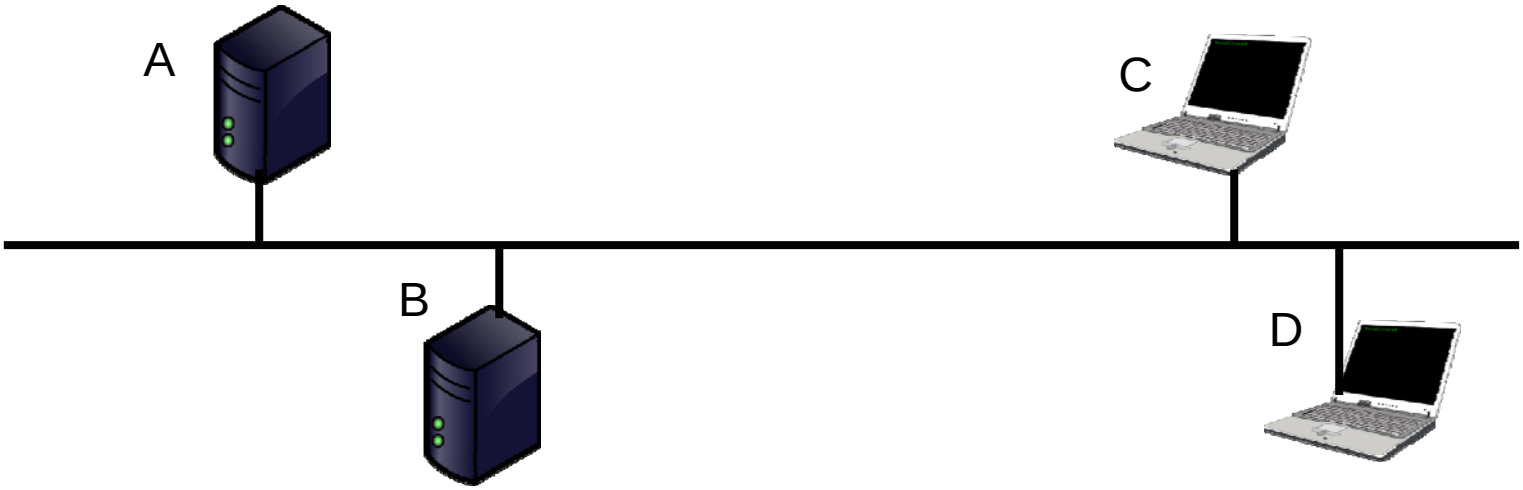
CSMA/CD Standards

- Originated from the DIX Ethernet standard
- Designed by Bob Metcalf in 1973
- IEEE commenced standardising CSMA/CD in February 1980, hence 802 committee
- Now a family of standards
- more than a billion cards have been sold
- 48 bit unique NIC (MAC) address

IEEE 802.3 family

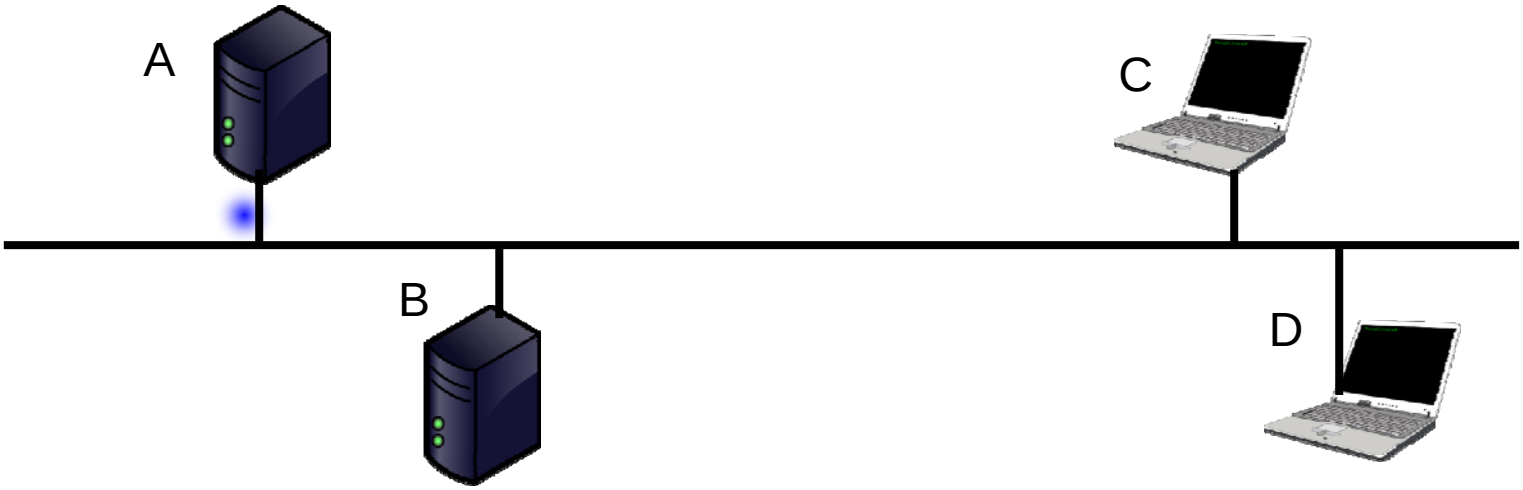
- 802.3 (1983) 10Base5
- 802.3a (1985) 10Base2
- 802.3i (1990) 10Base-T (cat 3/4)
- 802.3j (1993) 10Base-F
- 802.3u (1995) 100Base-TX (cat 5), 100Base-FX
- 802.3z (1998) 1000Base-X
- 802.3ab (1999) 1000Base-T (cat5/6)
- 802.3ae (2003) 10GBase-over Fibre
- 803.3an (2006) 10GBase-T (cat 6/7)
- P802.3ba (2009 -10) 40 Gbps to 100 Gbps

How CSMA/CD Works (1)



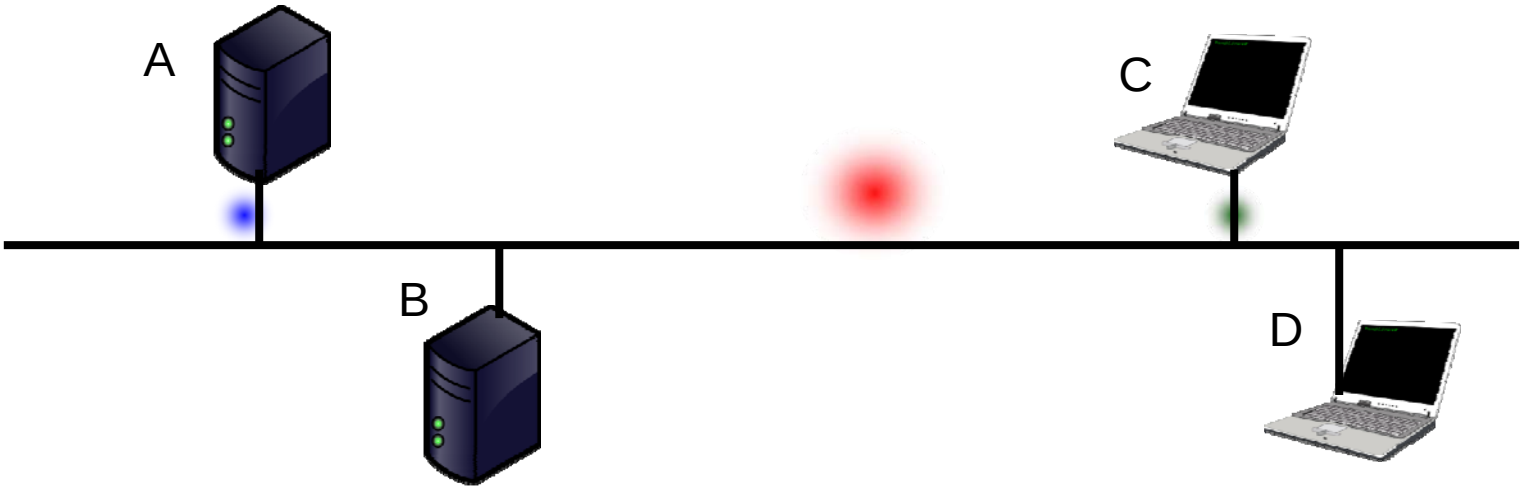
- All computers are listening
- No activity on the bus

How CSMA/CD Works (2)



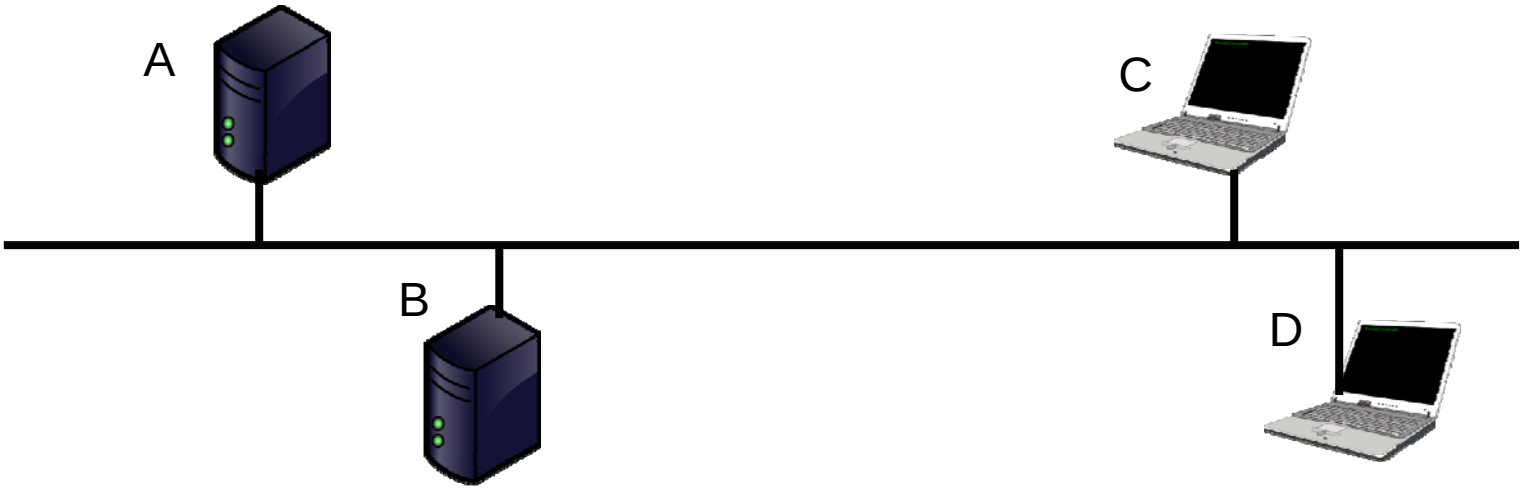
- A decides to transmit to C
- B, C, D do not transmit
- C receives data

How CSMA/CD Works (3)



- A decides to transmit to C
- C also decides to transmit to A
- B, D do not transmit
- Collision occurs

How CSMA/CD Works (4)



- A and C wait a random time
- B and D listen to the bus
- B and/or D can decide to transmit
- at the end of the wait A and C can transmit

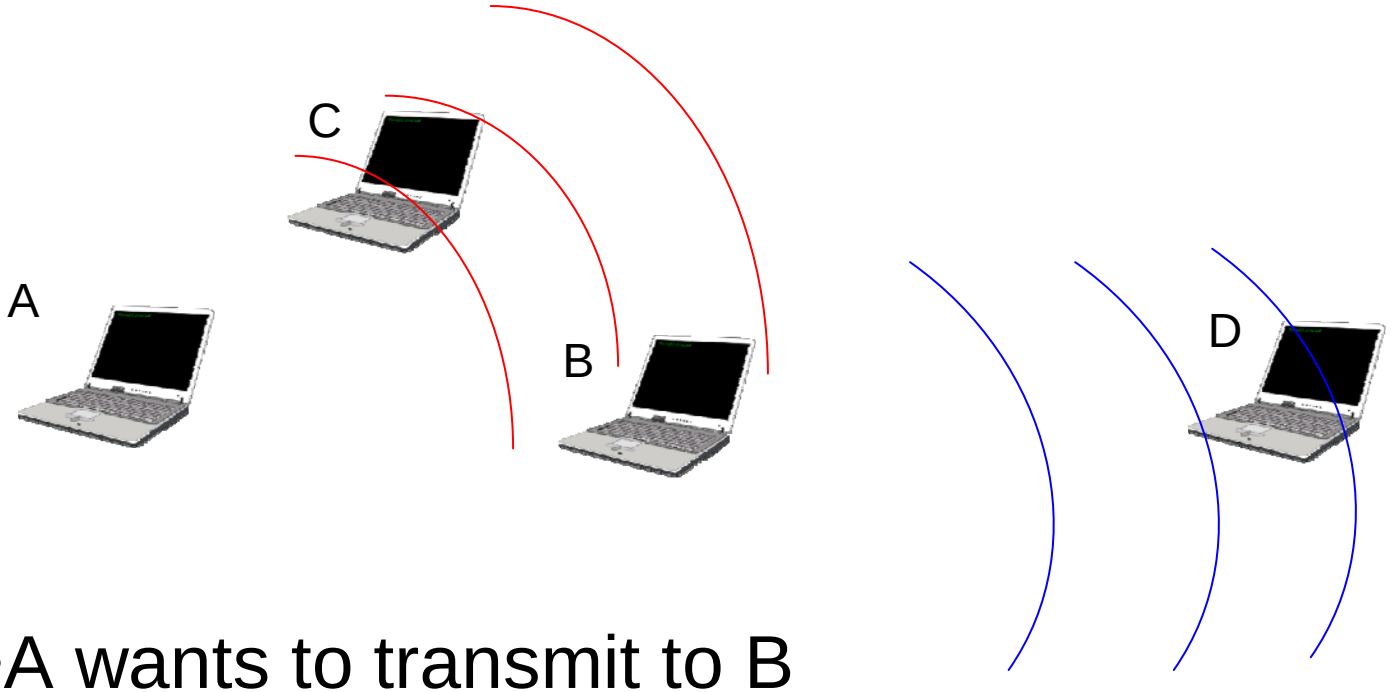
How CSMA/CD Works

- Slow speeds can use hubs or switches
- High speeds require the use of switches
- Use of switches improve performance as collisions are avoided on switched connections

Wireless LANs

- Uses Radio Frequency (RF) in the GHz band to transmit and receive data over air.
- IEEE 802.11 standards family
  - 802.11b (2.4 GHz/11 Mbps), 802.11g (2.4 GHz/54 Mbps)
  - Proprietary enhancements
    - 802.11b+ (22 Mbps), 802.11 Super g (108 Mbps)
  - 802.11a (5 GHz/54 Mbps)
  - 802.11n (100-300 Mbps) in the future
- Typical operating ranges are
  - Indoor - 30m at 11 Mbps and 90m at 1 Mbps
  - Outdoor – 120m at 11 Mbps and 460m at 1Mbps
  - Inverse relationship between data rate and range

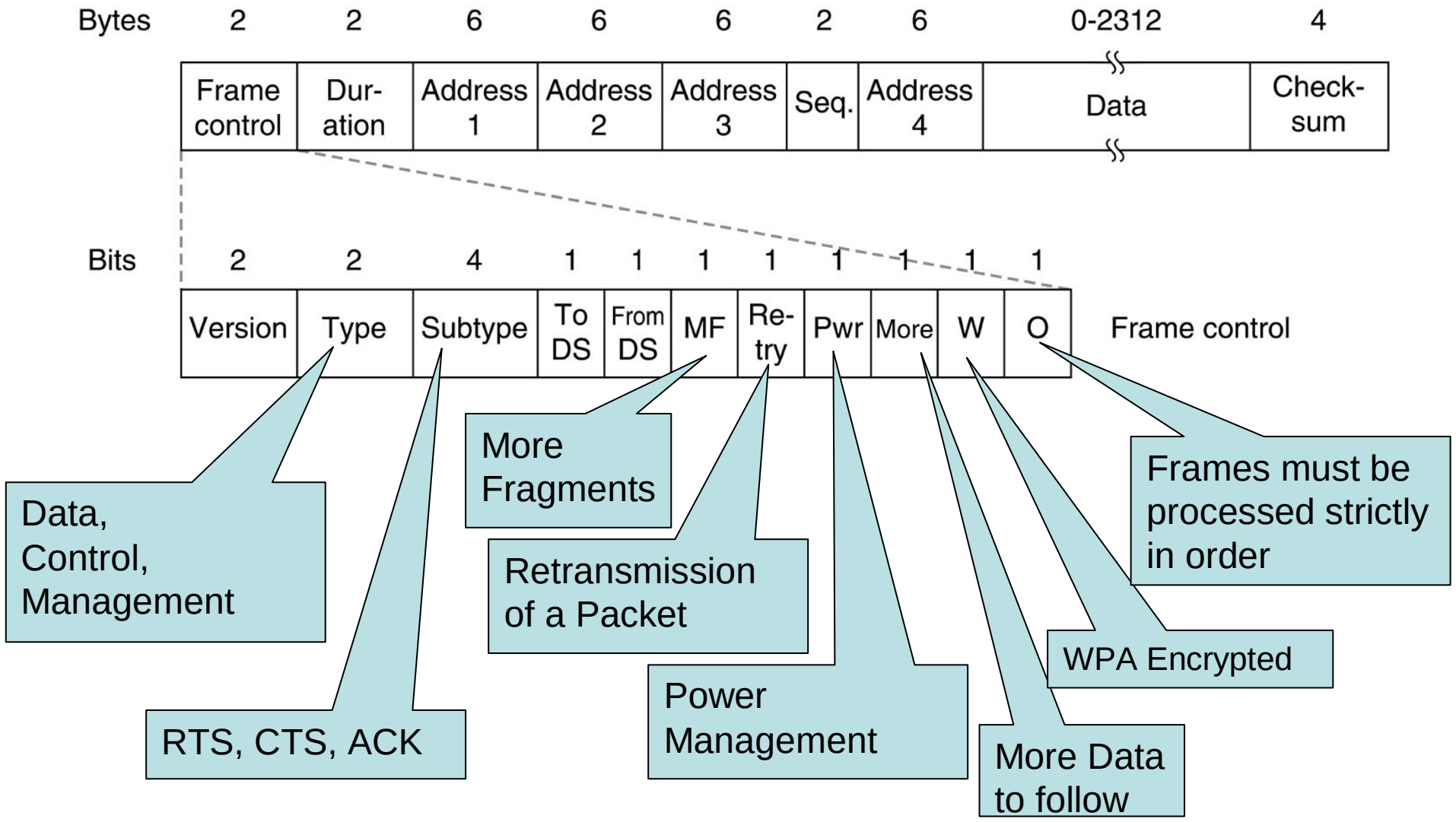
How CSMA/CA Works



- A wants to transmit to B
- C within range of A
- D is within range of B, but not within A

IEEE802.11 Data Frame Structure

Source: Tanenbaum (2003)



IEEE802.11 Data Frame Structure

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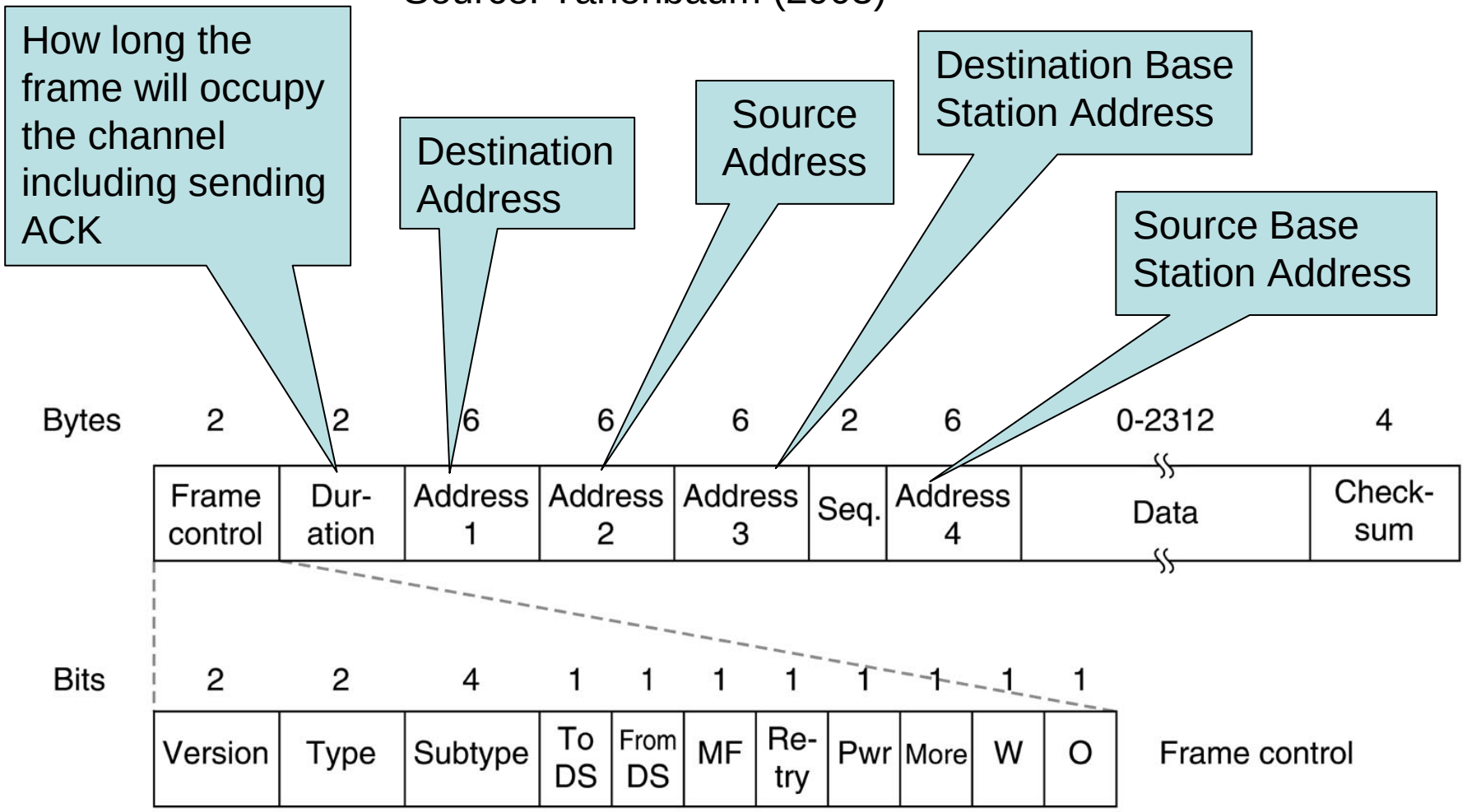
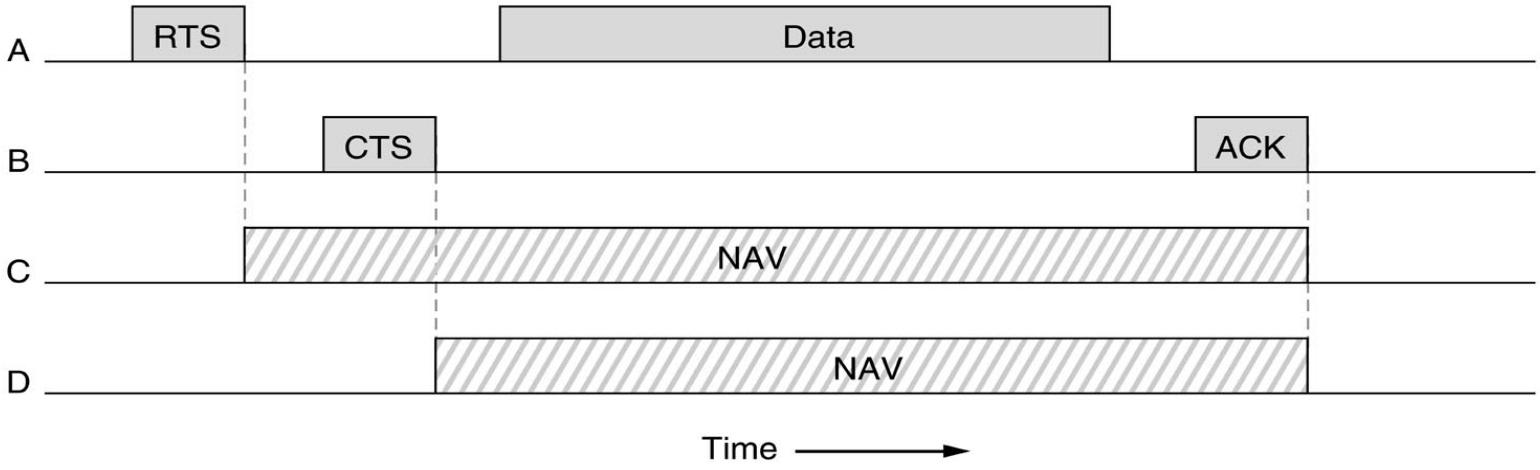


How CSMA /CA works



- C hears A's RTS and sets Network busy for the duration including ACK
- D hears B's CTS and sets Network Busy

Grid as an example of Distributed Computing