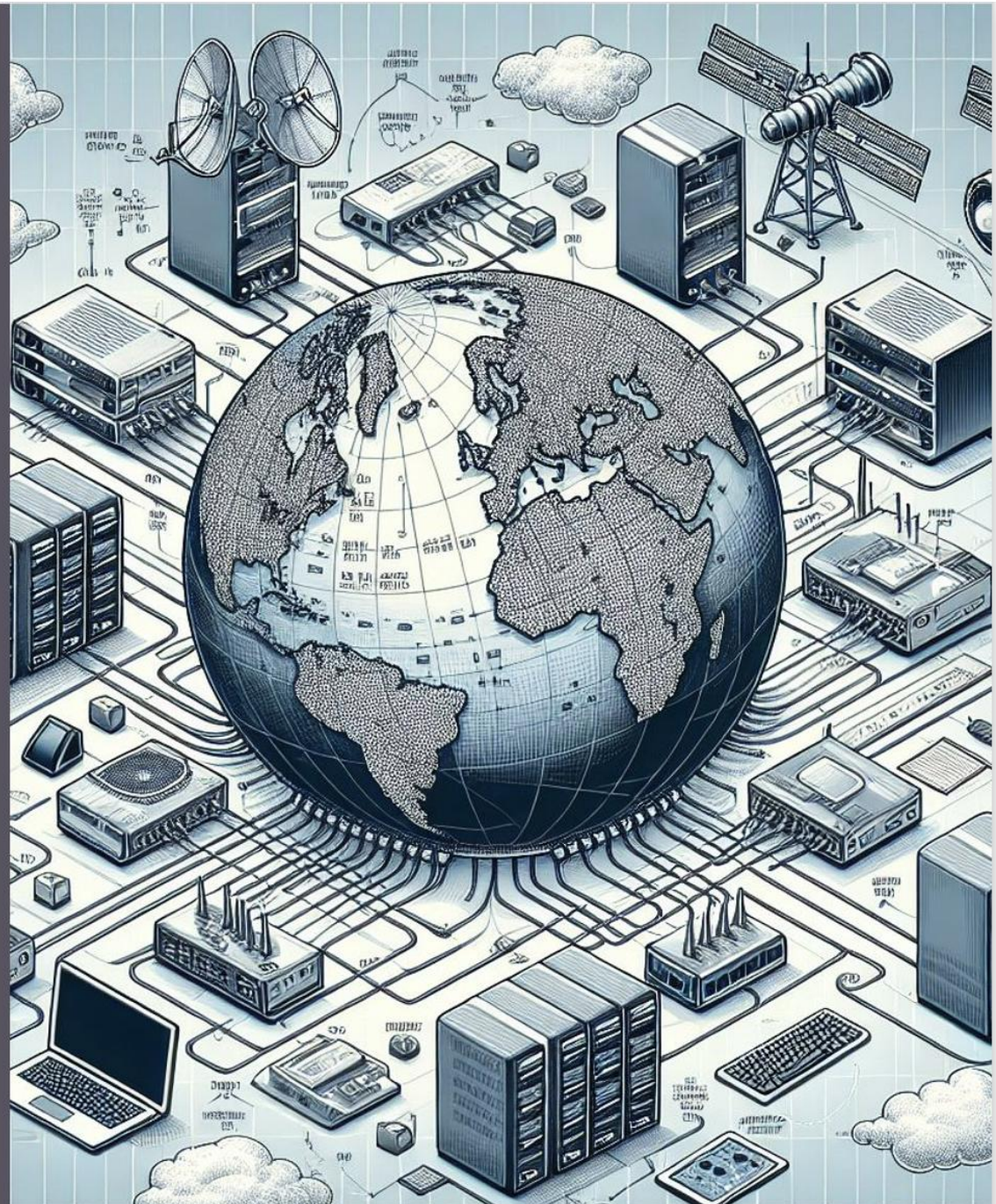
UAB COLLEGE OF ARTS AND SCIENCES
The University of Alabama at Birmingham
Department of Computer Science

CS 334/534 NETWORKING

Dr. Ragib Hasan

Lecture 2.2:
Link Layer and Ethernet

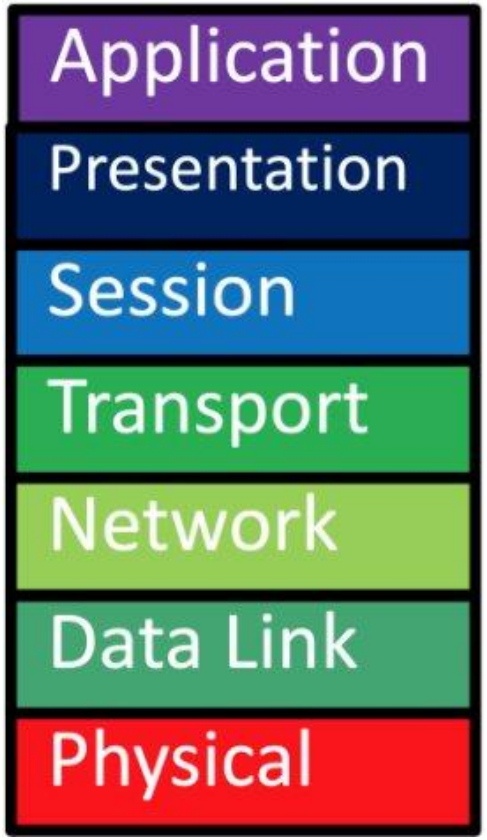


Lecture goals

- Introduce Ethernet
- Communication types
- Slot times and collision
- Exponential Backoff Algorithm

- Book reference: Chapter 2, section 2.1.1 to 2.1.6

Link Layer



- **Service**
  - Data framing: boundaries between packets.
  - Media access control (MAC).
  - Per-hop reliability and flow control.
- **Interface**
  - Sends one frame between two hosts connected to the same media.
- **Protocols**
  - Physical addressing (MAC address)

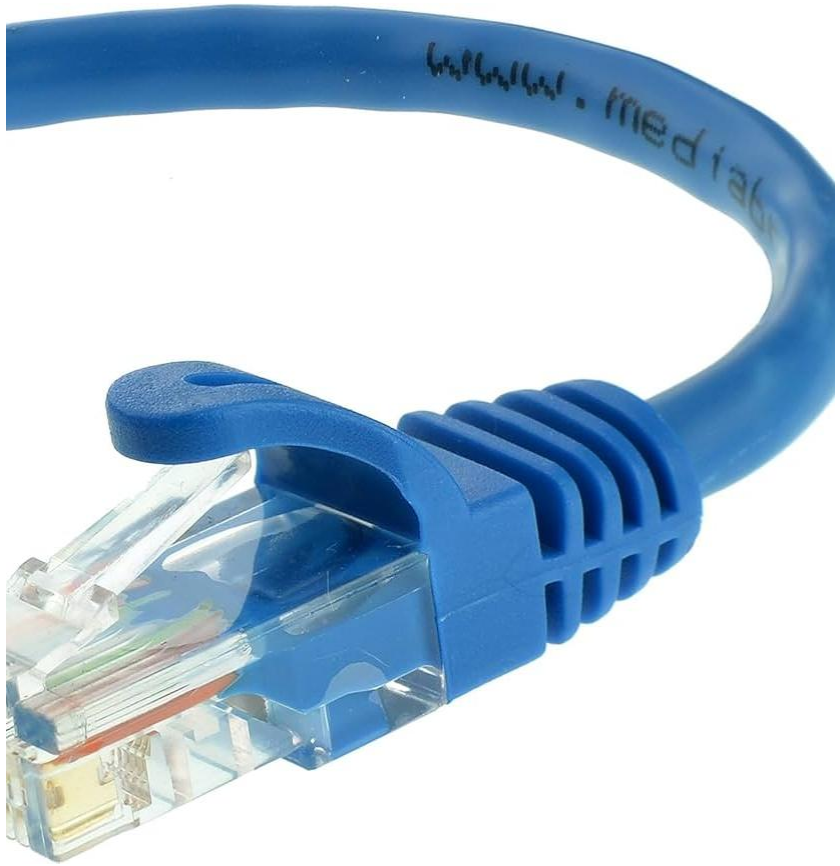
Example: Ethernet, WiFi, etc.

Ethernet

Ethernet is the traditional technology for connecting devices in a wired local area network (LAN) or wide area network

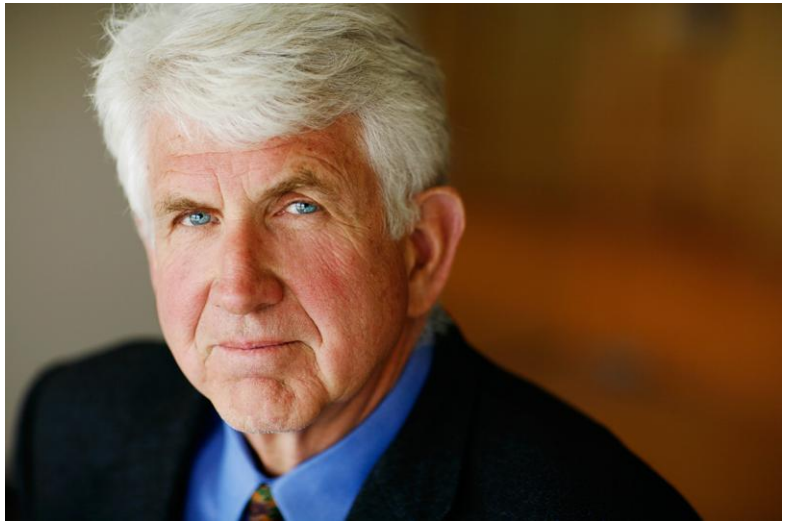
Ethernet typically operates at 100 Mbps (2020) or Gigabit speeds, with server rooms often using Gigabit or even 10 Gigabit Ethernet.

Despite being obsolete, the original 10 Mbps Ethernet provides insights into collision management, still relevant in wireless networks.

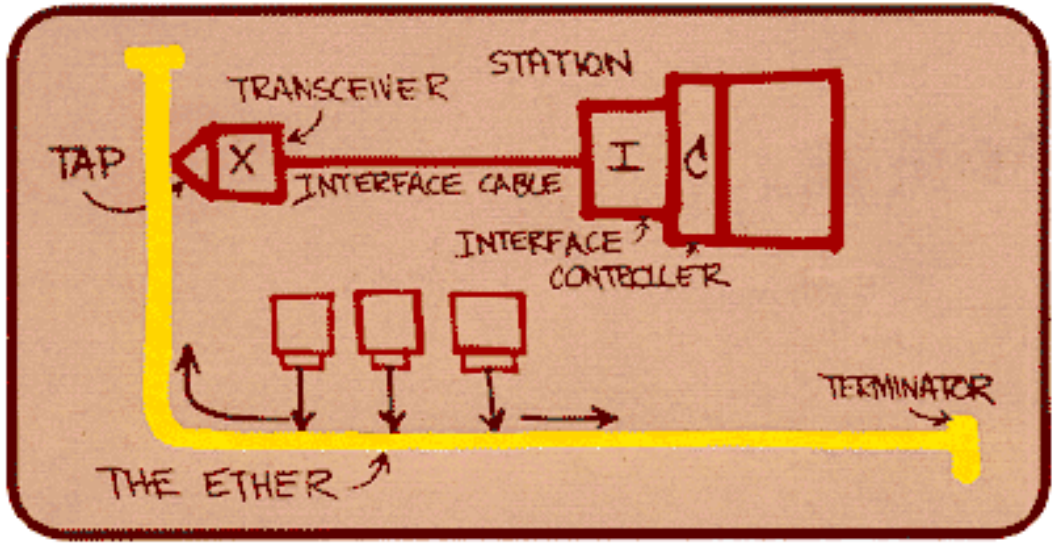


History

- The 1976 Ethernet specification by **Metcalfe and Boggs** (10 Mbps)
- Used **coaxial cables** in a passive design for simplicity and reliability
- **Collisions occurred** when two stations transmitted simultaneously, with signals lost as a result.

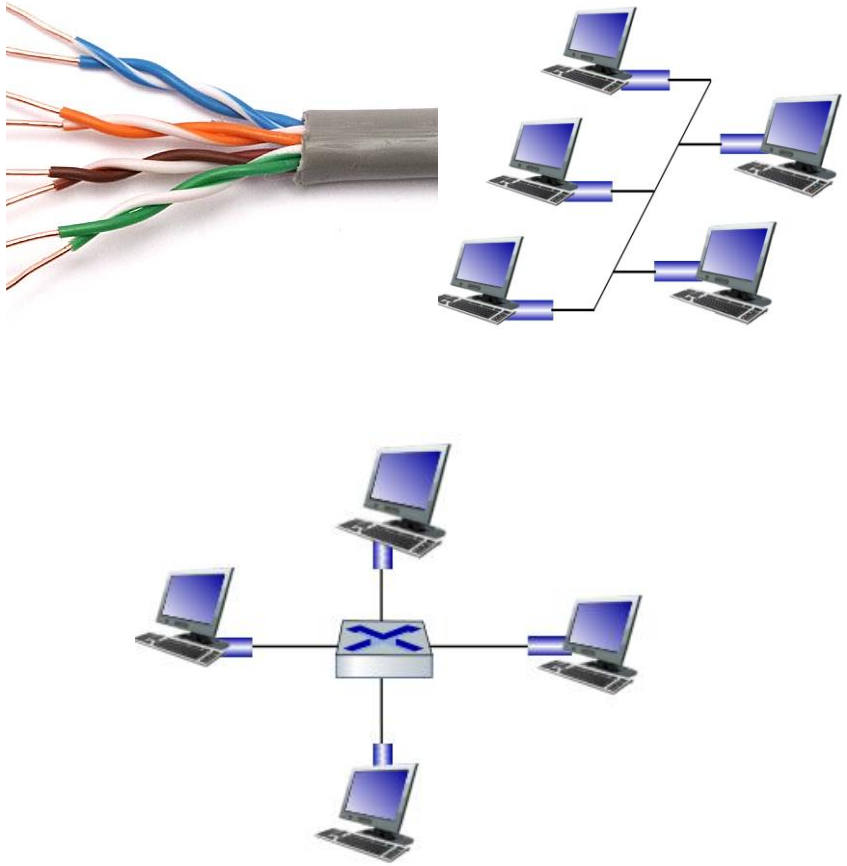


Bob Metcalfe: Ethernet co-inventor, 2022 ACM Turing Award recipient



Metcalfe's Ethernet sketch

History (Cont.)



- Originally, Ethernet networks used **one long cable (twisted pair**) to connect all devices. Repeaters allowed multiple cable segments to be joined together, **forming tree-like structures**. This setup led to the **development of "star" networks**, where every device connected to a central hub instead of one long cable.
- **Switches:** Replaced repeaters, dividing the network into **smaller parts** to prevent collisions, eventually eliminating them altogether.
- **Redundant Links:** At first, Ethernet didn’t allow extra connections in case of failure, but in 1985, the **Spanning Tree Algorithm** made it possible to activate backup links when needed. Later, TRILL and SPB introduced full support for loops and redundant paths.

Communication Type

Unicast

- Sending data from a **one sender to a single specific receiver**. It is a one-to-one communication model.
- Example: Web browsing, Sending emails

Multicast

- Sending data from **one sender to a group of receivers** (multicast group). It is a one-to-many communication model.
- Example: Real-time updates in multiplayer games, Live streaming

Broadcast

- Sends data from **one sender to all devices in the network**. It is a one-to-all communication model.
- Example: Announcing Wi-Fi Availability, Smart Home Device Discovery

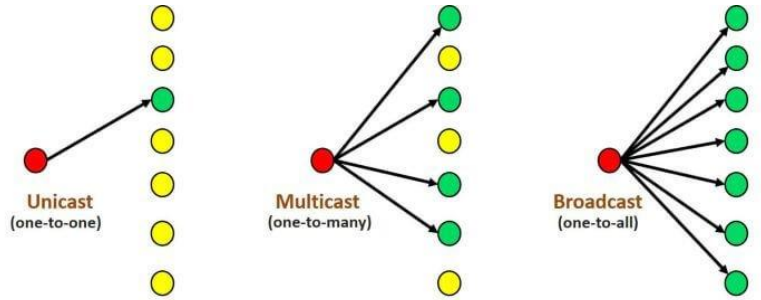


Fig. 9:: Ethernet packet with header fields

Ethernet Packet Format

- **Source and Destination MAC Address (48 bits each):**
  - If adapter receives frame with matching destination address, or with broadcast address (e.g., ARP packet), it passes data in frame to network layer protocol
  - Otherwise, adapter discards frame

Fig. 9:: Ethernet packet with header fields

Ethernet Packet Format

- **Type (16 bits): Indicates higher layer protocol**
  - 0x0800: IPv4 (Internet Protocol Version 4)
  - 0x0806: ARP (Address Resolution Protocol)
  - 0x86DD: IPv6 (Internet Protocol Version 6)
  - 0x8847: MPLS (Multiprotocol Label Switching)
  - Used to demultiplex up at receive

Fig. 9:: Ethernet packet with header fields

Ethernet Packet Format

- **Data (up to 1500 bytes):** The actual payload.
- **CRC (32 bits): Cyclic Redundancy Check at receiver**
  - A checksum added by hardware for error checking.
  - Error detected: frame is dropped

Fig. 9:: Ethernet packet with header fields

Ethernet Packet Format

- **Additional: Preamble (64 bits)**
  - Used to synchronize receiver, sender clock rates
  - 7 bytes of 10101010 followed by one byte of 10101011

Slot Time and Collisions

Diameter

- The **maximum distance** between any two stations in an Ethernet network, known as the diameter, is capped at 232 bits (464 bits round trip).

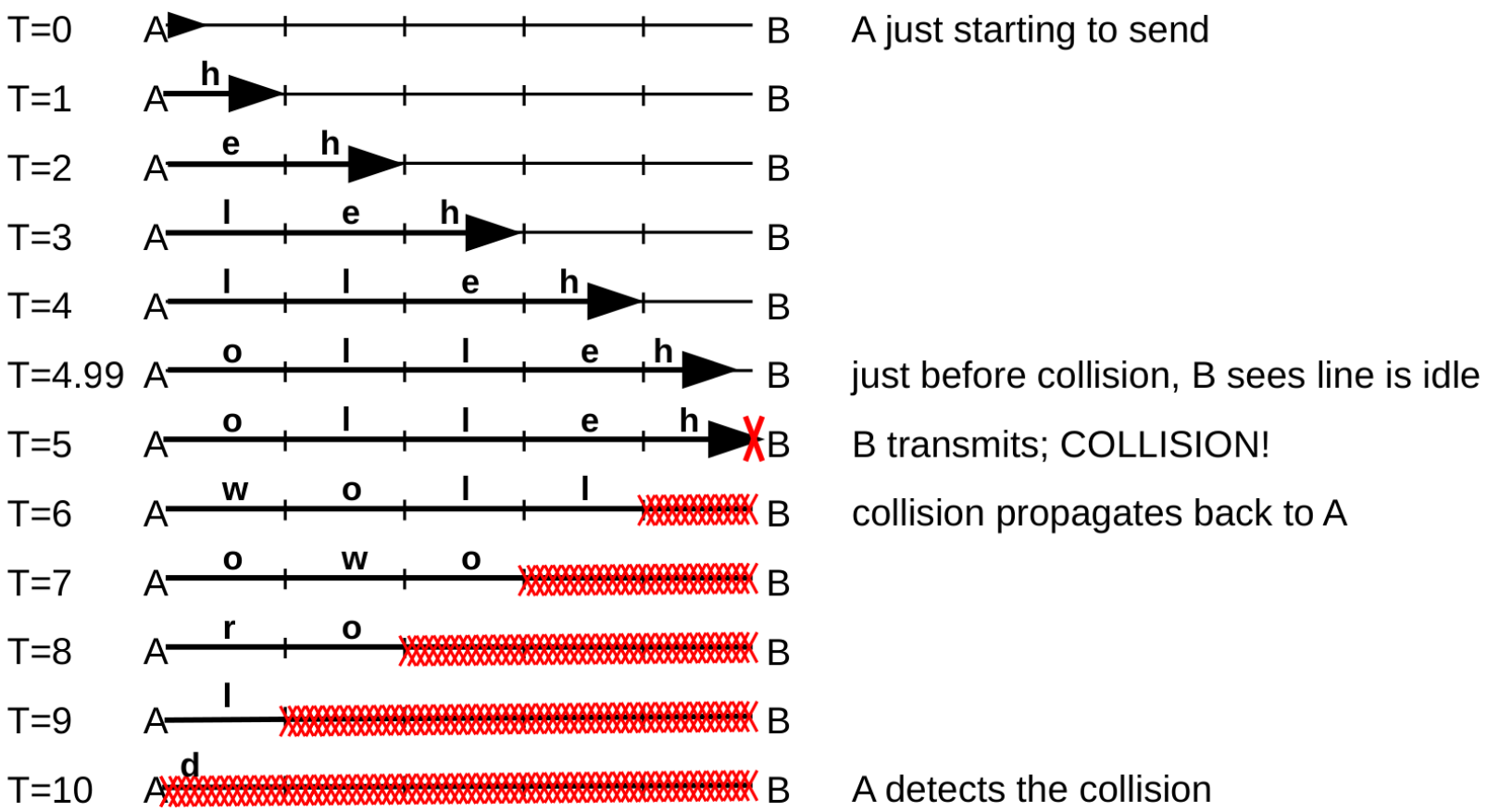
Slot Time:

- Defined as the **time to send 512 bits** (64 bytes) in an 10Mbps line, equivalent to 51.2 µsec.
- Ensures that after one slot time, no collisions can occur, as all stations recognize ongoing transmissions and wait for completion. This means the transmitting station has "acquired the network."

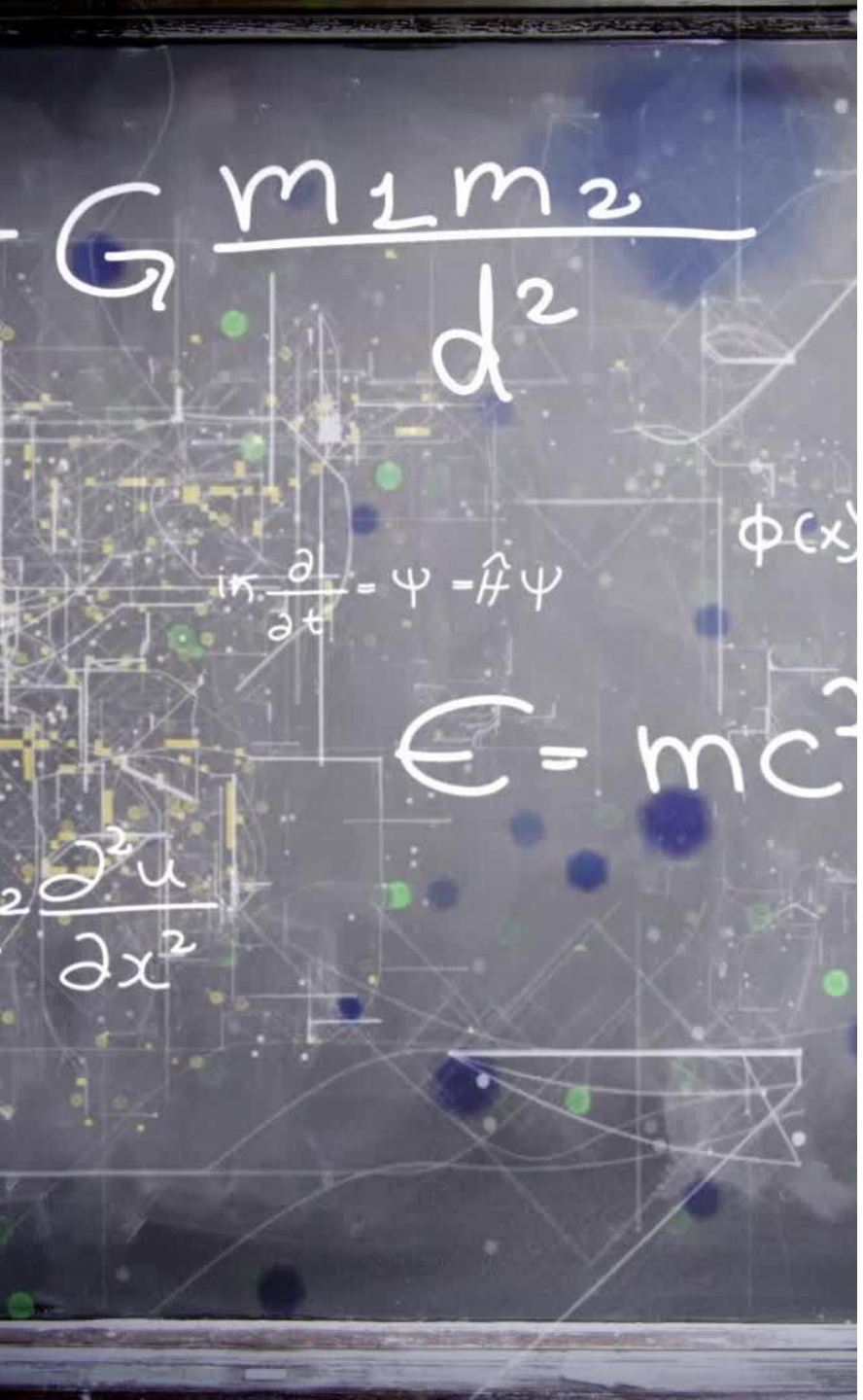
Collisions and Minimum Packet Size:

- Collisions can be detected within the slot time, necessitating a **minimum packet size of 64 bytes** (46 bytes for data). Smaller packets **might fail to detect collisions**, reducing throughput.

Slot Time and Collisions



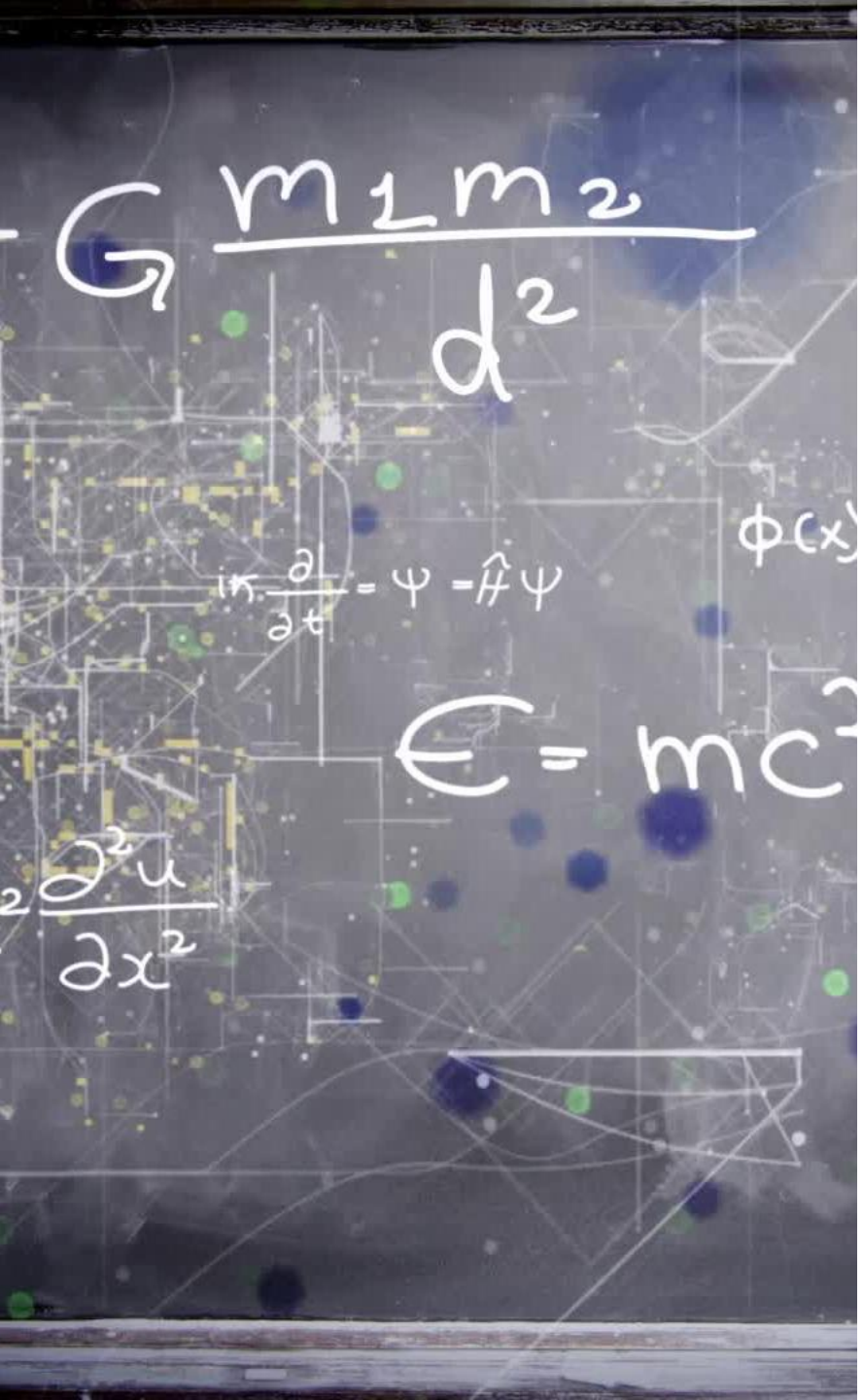
- A and B are 5 units apart
- A begins sending “helloworld” at T=0
- B starts sending just as A’s message arrives, at T=5 as B found line is idle
- A doesn’t discover the collision until 10 units have elapsed, which is twice the distance



Exponential Backoff Algorithm

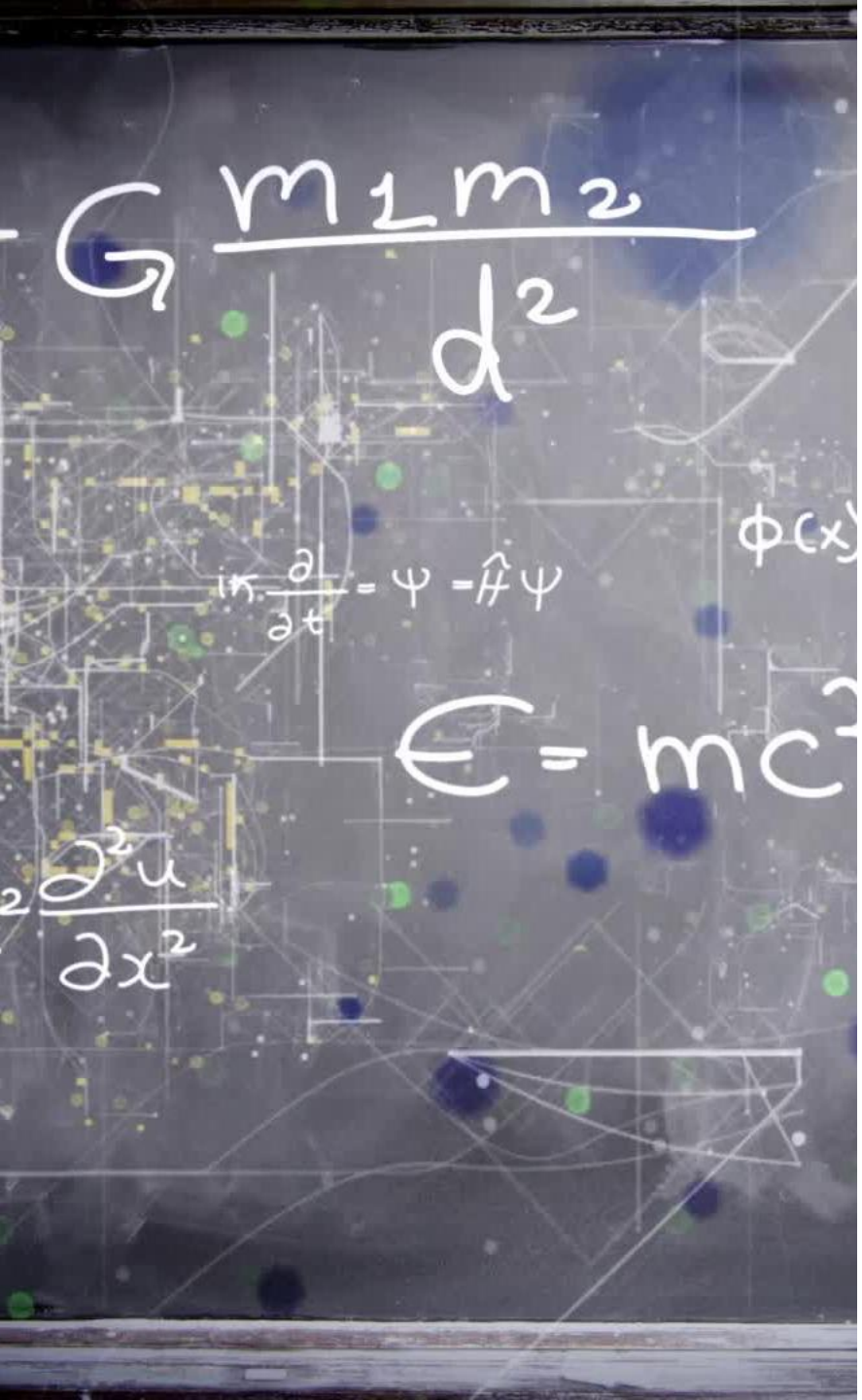
The exponential backoff algorithm **manages retransmissions** after collisions in Ethernet by progressively **increasing the waiting time**

- **Carrier Detection**: The sender listens for an idle line before transmitting.
- **Inter-Packet Gap**: If line is busy, wait for sender to stop and then wait an additional **9.6 microseconds (96 bits).** One consequence of this is that there is always a 96-bit gap between packets, so packets do not run together.
- **Collision Monitoring**: During transmission, the sender monitors for collisions.



Exponential Backoff Algorithm

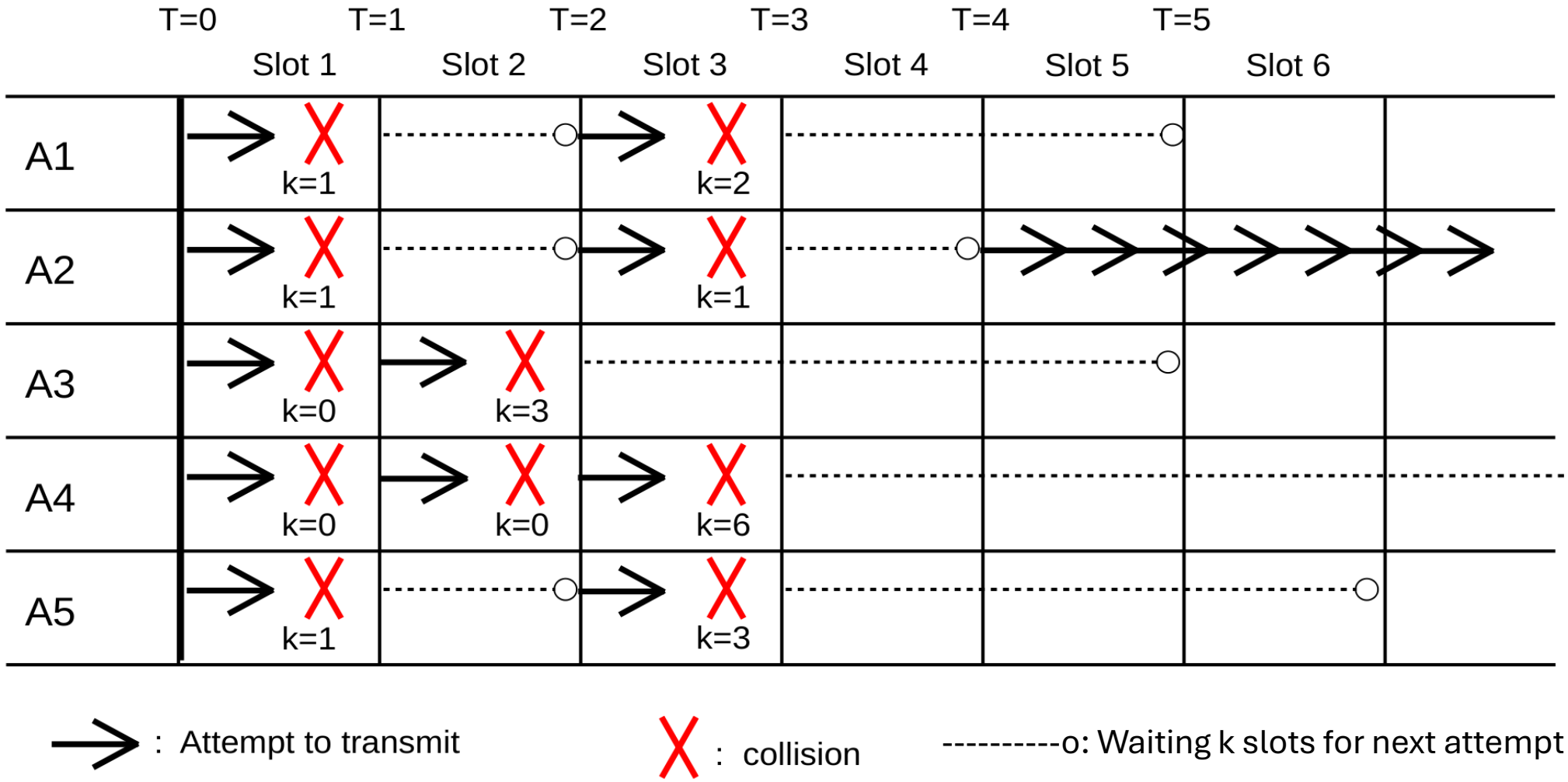
- **Collision Handling:** If a collision occurs:
  - Send a **jam signal** to notify all stations.
  - Choose a backoff time using the formula ***k*×51.2 μs**, where k is randomly selected based on the transmission attempt N.
  - **N≤10: k is randomly chosen from $[0,2^N)$**
  - **11≤N≤15: k is chosen from [0,1024)**
  - Retry transmission after the backoff period, starting from step 1.
- **Give Up:** After 16 failed attempts (N=16), the sender stops trying.



Exponential Backoff Algorithm

- After each collision, the range of **possible backoff times doubles**, reducing the chance of immediate recollision.
- Probabilities of recollision for two hosts decrease with increasing N.
  - **N=1: 50% chance.**
  - **N=2: 25% chance.**
- Maximum wait times:
  - **N=10: 52 ms.**
  - **N=15: 1.5 seconds (if no cutoff was applied).**
- The algorithm relies on **the sender detecting collisions while still transmitting**, ensuring it knows to resend the packet.

Exponential Backoff Algorithm



Note: We assume collision detection always takes one slot time