

## Hidden and Exposed Terminal Problem in ALOHA Systems

In wireless communication, two common challenges that affect data transmission are the Hidden Terminal Problem and the Exposed Terminal Problem. The hidden terminal problem arises when two nodes that cannot sense each other's signals, such as node A and node C, attempt to transmit to a common receiver (node B). Since A and C are unaware of each other, they may transmit simultaneously, leading to a collision at B. On the other hand, the exposed terminal problem occurs when a node, say C, refrains from transmitting because it senses another nearby transmission (such as B to A), even though its own transmission to a different node (like D) would not actually cause interference. This leads to under-utilization of the channel and reduced efficiency.

When using Pure ALOHA, the protocol does not attempt to avoid collisions -- nodes transmit data as soon as they are ready, without sensing the channel. As a result, the hidden terminal problem remains severe since nodes cannot detect other transmissions and may cause frequent collisions. The exposed terminal problem is also unresolved, as nodes may unnecessarily avoid transmitting even when they could have done so safely. Overall, Pure ALOHA suffers from high collision rates and poor channel utilization.

Slotted ALOHA improves slightly by dividing time into slots, allowing transmissions only at the beginning of each slot. This reduces the chance of overlapping transmissions, but it does not solve the hidden terminal problem because two hidden nodes can still choose the same slot. Similarly, the exposed terminal problem persists, as the protocol lacks any mechanism to differentiate between harmful and non-harmful interference. While Slotted ALOHA is more efficient than Pure ALOHA, it still struggles with both terminal issues.

Reservation ALOHA, however, provides a significant improvement. It introduces a two-phase approach -- first, a reservation phase where nodes contend to reserve a time slot, and then a data

transmission phase where only successfully reserved nodes transmit. This structure helps detect and reduce collisions early, especially due to hidden terminals. While it does not fully eliminate the exposed terminal problem, the improved coordination reduces unnecessary deferrals, leading to better channel utilization. Among the ALOHA variants, Reservation ALOHA is the most efficient and robust in handling the hidden terminal problem.

In conclusion, while Pure and Slotted ALOHA suffer heavily from both hidden and exposed terminal issues, Reservation ALOHA offers a better solution by reducing collisions through slot reservation. However, to fully resolve both problems, more advanced MAC protocols such as CSMA/CA with RTS/CTS (used in Wi-Fi) are required.