

Scribe Writing

Introduction of Probability in Computer Systems

Networking-Based Project

Course Code: CSE400

Group Number: 13

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Q1. What is the problem being studied in this project?

Solution:

The main issue that is to be examined within the framework of the present project is the effective and equitable usage of common communication channel in wireless computer networks in case of uncertainty. In wireless local area networks (WLANs), there is no centralization in the transmission of data packets by multiple nodes of a physical medium. Because nodes work as asynchronous ones, they will tend to transmit packets at the same time, which will lead to the packet collisions.

Packet collisions are a major factor, which makes the network slow because they consume bandwidth and cause delays in retransmission. The characteristics of the wireless systems versus wired networks are that with wiring, deterministic scheduling can be assumed since the nodes are not globalized about network activity and that this network is continually being reconfigured. Thus, the deterministic access control is ineffective.

Probabilistic access schemes including the Binary Exponential Backoff (BEB) algorithm are applied to solve this problem. BEB adds randomization in transmission so as to alleviate multiple collisions. This project aims at learning the role of probability in the channel access decision and the analysis of network performance through probabilistic modeling to enhance performance.

Q2. Why is probability essential in modeling this networking system?

Solution:

The modeling of this system of networking requires probability since the trait of uncertainty is a natural feature of wireless communication. The nodes in the network do not know when other nodes would be transmitting hence deterministic prediction is not possible.

Randomness is also introduced by the backoff mechanism so that nodes do not synchronize. In case nodes were subject to a fixed waiting time, repeated collisions would be realized. The use of random backoff intervals allows nodes to eliminate the chances that they will collide several times, but nodes also cause the system behavior to be unpredictable.

Moreover, idle slots, successful transmissions as well as the packet collisions are random events. Probability theory has the mathematical tools that are required to model these events and estimate their probability, and performance measures, like throughput, delay, and fairness. In the absence of probabilistic modeling, such decentralized systems would not be analyzable.

Q3. What are the sources of uncertainty in the Binary Exponential Backoff mechanism?

Solution:

The Binary Exponential Backoff algorithm has a number of sources of uncertainty both stemming out of the design of the protocol and the dynamics of the network. To begin with, the network is in decentralized mode which means that no nodes are coordinated to make decisions.

One of the greatest sources of uncertainty is the random choice of the backoff counter. Once an idle channel is detected, all the nodes wait randomly at the contention window by randomly choosing a wait time. This choice is different in each node and each transmission attempt, thus, the system is not predictable.

The other parameter of uncertainty is the number of nodes trying transmission in a particular time slot. Although all nodes may be using the same protocol, independent random decisions cause different transmission patterns. Consequently, every time slot can lead to an idle condition, a successful transmission or a collision. These ambiguities render the system to be stochastic.

Q4. Identify and explain the random variables used in the system.

Solution:

Several random variables are introduced to mathematically represent uncertainty in the networking system.

- **Backoff Time (R):** This is a discrete random variable that is the waiting time of a node until it attempts to be transmitted in time slots. It is usually uniformly distributed over the interval $[0, CW - 1]$, CW is the contention window size.
- **Slot Outcome (S):** This time slot variable is a random variable. There are a possible idle slot, a successful transmission or a collision.
- **Transmission Attempt Indicator (T):** This is a Bernoulli random variable indicating whether a node attempts to transmit in a particular time slot.
- **Number of Competing Nodes (N):** The effective number of active nodes is usually considered a constant but in fact, it adds randomness to the probability of collision and channel contention.

These random variables collectively capture the probabilistic behavior of channel access and packet transmission in the network.

Q5. How is the Binary Exponential Backoff process modeled probabilistically?

Solution:

Binary Exponential Backoff is a stochastic process that is defined as a discrete time Markov chain. The Markov chain states are combinations of the backoff stage and the backoff counter value which is at present.

The effect of a transmission attempt is state transitions. In case the transmission is successful, then the contention window is initialized to the minimum value. The contention window is doubled in case of collision, and this will increase the variety of the possible backoff values and minimize the possibility of repeated collisions.

The probability of collision and successful transmission are used to derive transition probabilities where the first probability is dependent on the number of competing nodes and the second probability is the probability of a node achieving the next transmission. Such a probabilistic model can be used to study long-term behavior of systems with steady-state probabilities.

Q6. What assumptions are made in the probabilistic analysis, and why are they necessary?

Solution:

The probabilistic analysis simplifies the analysis by several assumptions that are simplifying in nature. It is also assumed that the network is in saturated state that is, each node is continuously ready to transmit packets. This removes any confusion as regards to traffic arrival procedures.

The channel is perfectly assumed; it has no errors of transmitters in terms of noise or interference. Terminal issues are not considered, and the nodes are all supposed to have the same backoff parameters and transmission capabilities.

These assumptions make the system very simple and enable the analysis to be based on probabilistic channel access and collision behavior only. Though these implications might not represent the actual networks in the real world, they are very helpful in understanding the basic functionality of the Binary Exponential Backoff mechanism.