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Bathroom Module:

In order to prove the correctness of our bathroom module we will analyze all possible states for entering and exiting. To enter the bathroom there are 3 possible states, the bathroom is vacant, the bathroom is occupied with same gender, or occupied with opposite gender. If the bathroom is vacant, there is nothing to be done, and the user simply enters the bathroom and sets the flag to its gender. Note that when the flag is being edited or viewed a mutex lock is employed as the flag is a critical section and should never be edited by two different entities at the same time. Therefore the vacant case is done, as the user simply grabs the lock and enters changing the flag and incrementing the number of occupants. If the user grabs the lock and the flag is set to their gender, then they simply enter and increment the number of occupants. The final case occurs when someone tries to enter but the bathroom is currently occupied by the other gender. In this case the user will grab the lock look at the flag and realize the bathroom is in use and cannot be entered, and will increment the number of users in queue, and simply wait on the conditional variable change. This conditional variable change will be looked at extensively in the leave section, but for now we will always assume that when a user is awoken from waiting the bathroom is vacant and therefore they simply use the same case as entering a vacant bathroom.

The conditional variable change is used to determine when users in queue can enter the bathroom. The conditional variable change is only every changed from users leaving the bathroom. This is because there is an invariant that everyone waiting on the change signal is the same gender, and the opposite gender currently occupies the bathroom. Therefore this case will only be resolved once all the members in the bathroom leave. Therefore there are only two cases to the leave function. The first case being a user grabs the lock, decrements the number of users in the bathroom and leaves if it is above zero. The second case being that a user grabs the lock and leaves decrementing the number of users, and the current users drops to zero, this means no one is left in the bathroom and therefore this user will signal the conditional variable broadcast waking everyone in queue, and the first person from the queue to enter will behave with a vacant enter case and change the flag correspondingly.

From these 3 enter states and 2 leave states it is obvious that there can never be two people in the bathroom from opposite genders.

Queue:

The queue works very similar to how enter and leave work above. The queue is not actually a queue at all, instead if someone tries to enter the bathroom and the gender flag is not valid to enter, they simply wait on a conditional variable called change. Therefore many threads(users) could be waiting at the same time and once everyone has left the bathroom they will get signaled by the last person to leave and they all are awoken. Therefore it is not necessarily a queue in the sense that someone who just started waiting might get awoken before someone who has been waiting for a long time. But that is irrelevant as the bathroom is so large it can support an infinite number of people so there is no worry of order or unfairness. Therefore people who are waiting to enter will always be allowed to enter before someone else can come along due to the conditional variable change. We time users before and after their enter returns therefore we can keep track of statistics for each thread such as on average how long they were in queue for if they were at all.