Personal Communications Services

PCS_2021 Fall Final Project

Dynamic Priority Queueing of Handoff Request in PCS

(ICC 2001. IEEE International Conference on Communications. Conference Record Cat. No.01CH37240)

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Introduction

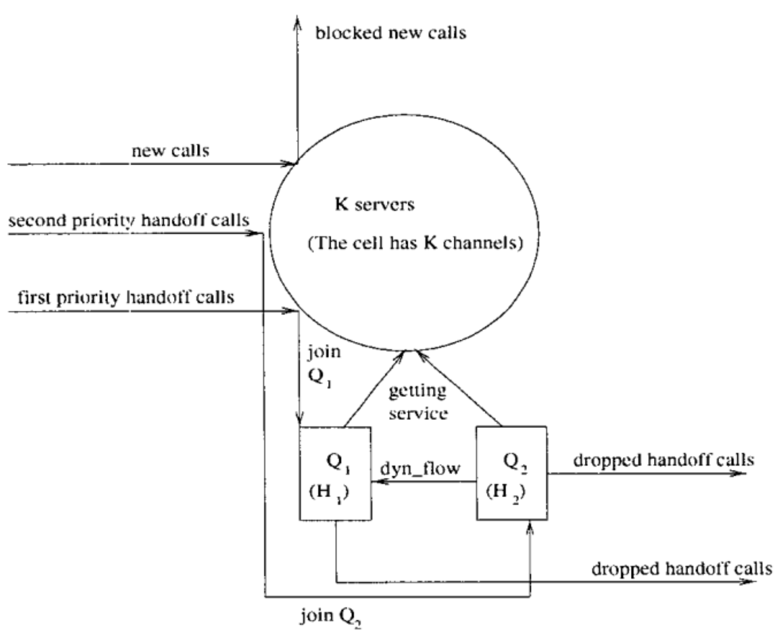
There are two main reason why handoff issue is becoming more and more critical: The first is the grow in demand for wireless communications, and this leads to the trend towards microcellular and picocellular wireless communications. The second is the development of multimedia services, which requires different priority of handoff request for different types of service(ex: voice, data, video).

For how a BST(Base station transmitter) handles handoff requests, previous work has analyze a FIFO priority queueing scheme based the RSS(received signal strength) and the speed of the MU(mobile user), but none of it has considered a time-dependent priority queueing(dynamic queueing) scheme, which the author of this paper proposed. The dynamic queue not only simulates different speed of different MU, but also considered different speed for a single MU in different time, for example, a MU may be waiting for bus at bus stop at this moment, but the next moment, he get on the bus, and his moving speed increase dramatically.

Problem Statement

Compares FIFO queue with dynamic queue, for the performance of handling handoff calls(dropping probability).

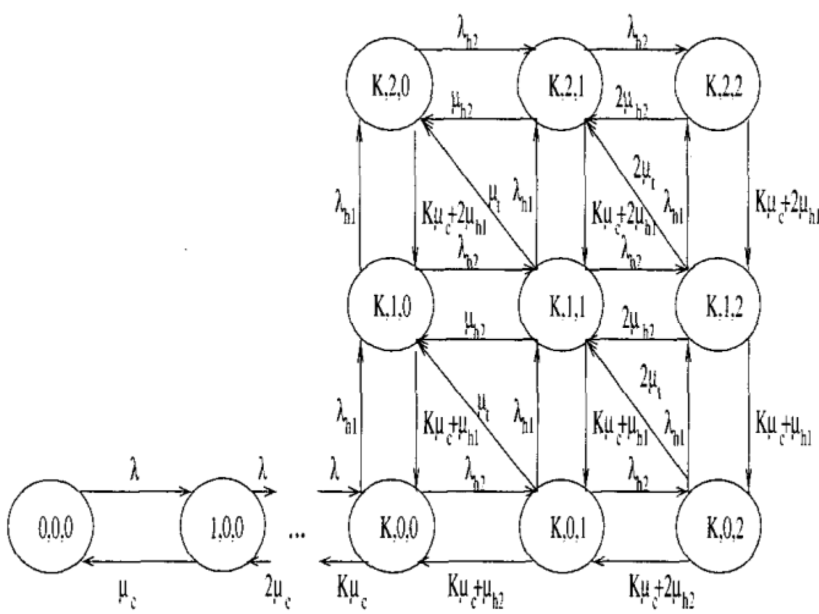
System Model & Notations



K servers(channels), when there is a free server, the new and handoff calls get service, if there is no free server, no queueing for new calls, and finite queueing for the two classes of handoff priorities, first priority calls will get service before second priority calls when the server is free again, and no exclusive reserved channels for these calls are assumed. The priority of a handoff request does depend on the waiting time in the queue, so there is a dynamic flow from Q2 to Q1.

- λ_n ,λ_h, λ_{h1}, λ_{h2} : The Poisson arrival rates for new call, handoff calls, I-st priority handoff calls, II-nd priority handoff calls, respectively.
- T_n, T_h, μ_n, μ_h : The channel holding time for new and handoff calls, which are random variables, exponentially distributed with means $\frac{1}{\mu_n}$ and $\frac{1}{\mu_h}$, respectively.
- T_{h1}, T_{h2}, μ_{h1}, μ_{h2} : The dwell time for new and handoff calls, which are random variables, exponentially distributed with means $\frac{1}{\mu_{h1}}$ and $\frac{1}{\mu_{h2}}$, respectively.
- T_c, μ_t : The transition time of II-nd priority handoff call to I-st priority handoff call, which is a random variable, exponentially distributed with means $\frac{1}{\mu_t}$.
- T_c, μ_c : The channel holding time, which is a random variable, exponentially distributed with means $\frac{1}{\mu_c}$.
- K : number of channels available in a cell.
- H_1, H_2 :The model has two finite queues for the two classes of handoff calls, capacity for the first class and the second class priority handoff calls, respectively.

Mathematics



This Dynamic queue handoff model is essentially a two dimensional markov chain, one can solve the steady state probability by writing down the global balance equations for the state diagram listed above, and solve the global balance equations. Once obtain the steady state probability, one can compute blocking probability and handoff dropping probability using the steady state probability, formula used is listed below.

For blocking probability P_B:

$P_B = \sum_{m1=0}^{H1} \sum_{m2=0}^{H2} P(K, m1, m2)$, where $P(k, m1, m2)$ is the steady state probability of the system which has k busy channels, m1 first priority calls in queue Q1, and m2 second priority calls in queue Q2, Q1's size is H1, and Q2's size is H2.

For dropping probability P_{hd}:

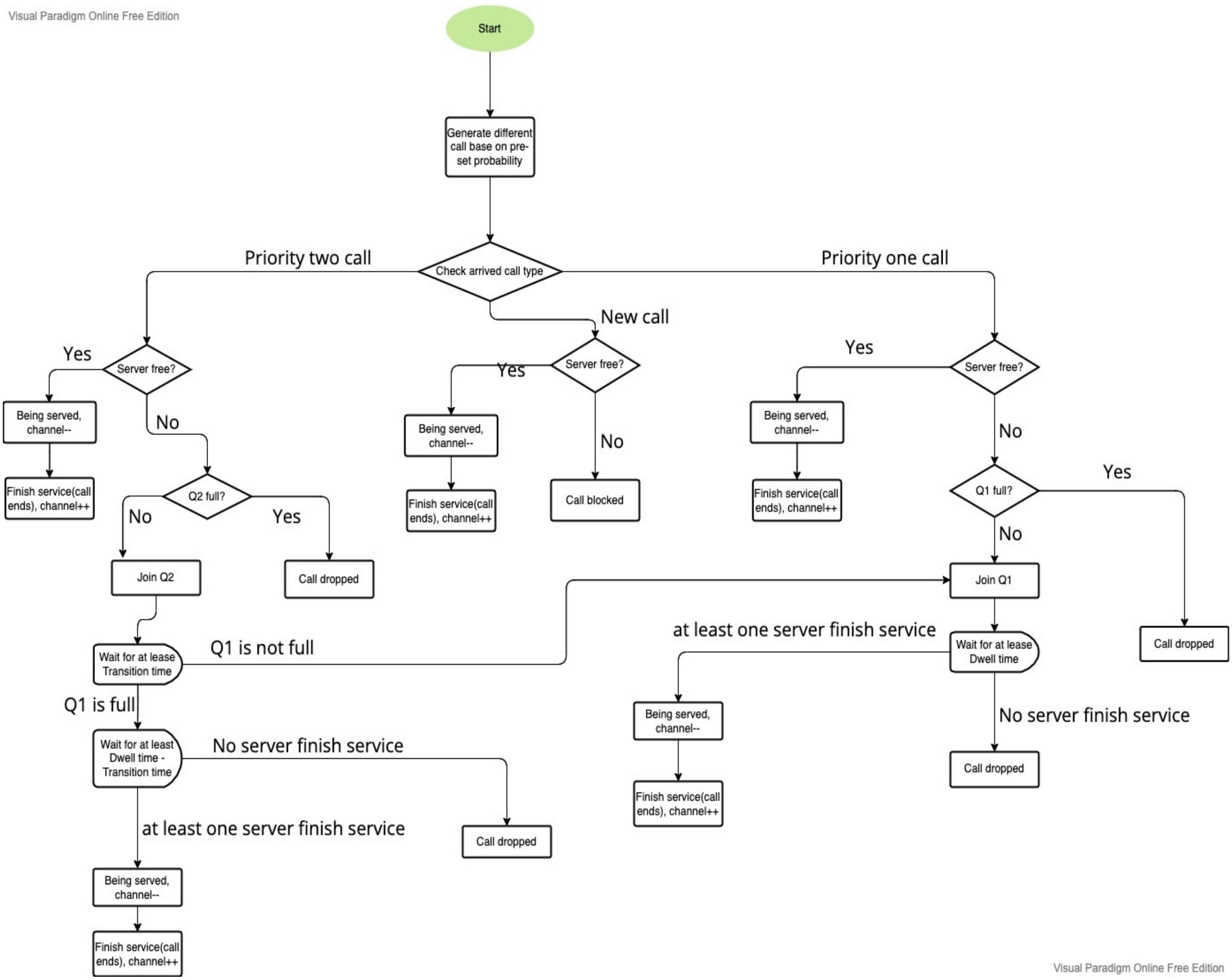
$$P_{hd} = \frac{\lambda_{h1}}{\lambda_h} P_{hd\ I\ priority} + \frac{\lambda_{h2}}{\lambda_h} P_{hd\ II\ priority}$$, where

$$P_{hd\ I\ priority} = \sum_{m2=0}^{H2} P(K, H1, m2) + \sum_{m1=1}^{H1} \sum_{m2=0}^{H2} P(K, m1, m2)\, P_I(K, m1, m2)$$

$$P_{hd\ II\ priority} = \sum_{m1=0}^{H1} P(K, m1, H2) + \sum_{m2=1}^{H2} \sum_{m1=0}^{H1} P(K, m1, m2)\, P_{II}(K, m1, m2)$$

$$P_I(K, m1, m2) = 1 - \prod_{i=1}^{m1} \frac{K\mu_c + (i-1)\,\mu_{h1}}{K\mu_c + i\,\mu_{h1}}, \quad P_{II}(K, m1, m2) = 1 - \prod_{i=1}^{m2} \frac{K\mu_c + (i-1)\,\mu_{h2}}{K\mu_c + i\,\mu_{h2}}$$

Simulation-Steps



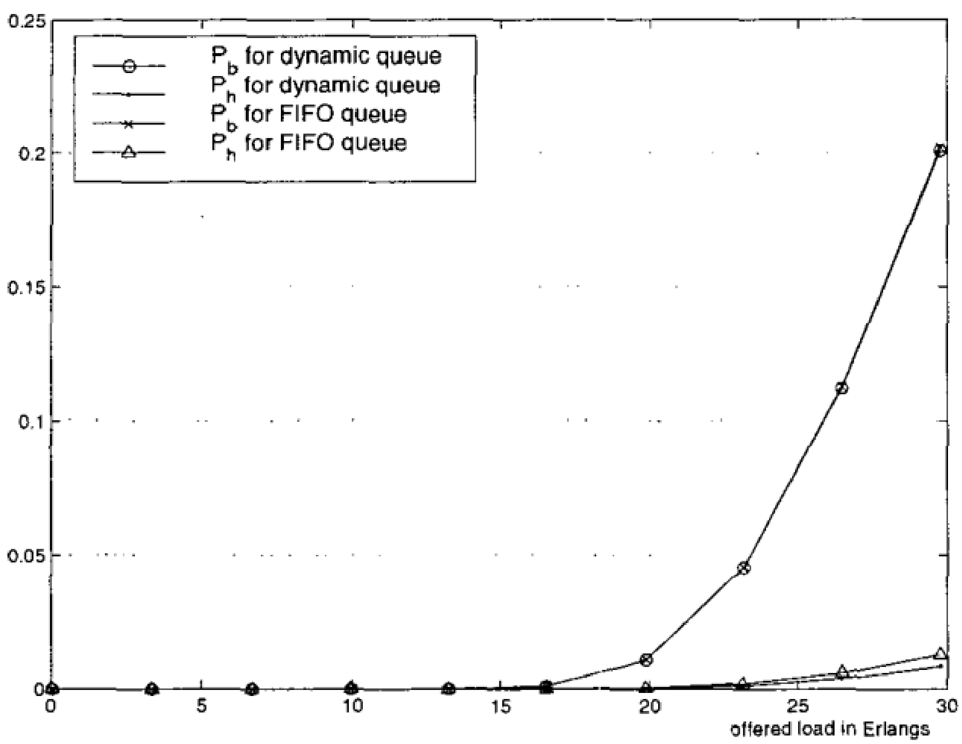
Simulation-Validation

We compute steady state probability of a simplified model, which only has 2 channels, and Q1, Q2's size are both set to 1(https://hackmd.io/Wen6lG5RTxmwrPxWDrCUKw), and then we run the simulation code(https://github.com/JJLIN1024/PCS_final_project), compare the steady state probability generated by the simulation code with the mathematical result, it the probability match, we know that the simulation code's logic is correct, then we scale up our simulation code by changing global parameter to simulate the paper's result, which has 30 channels, and Q1 Q2's size are both set to 5, finally analyze the simulation result.

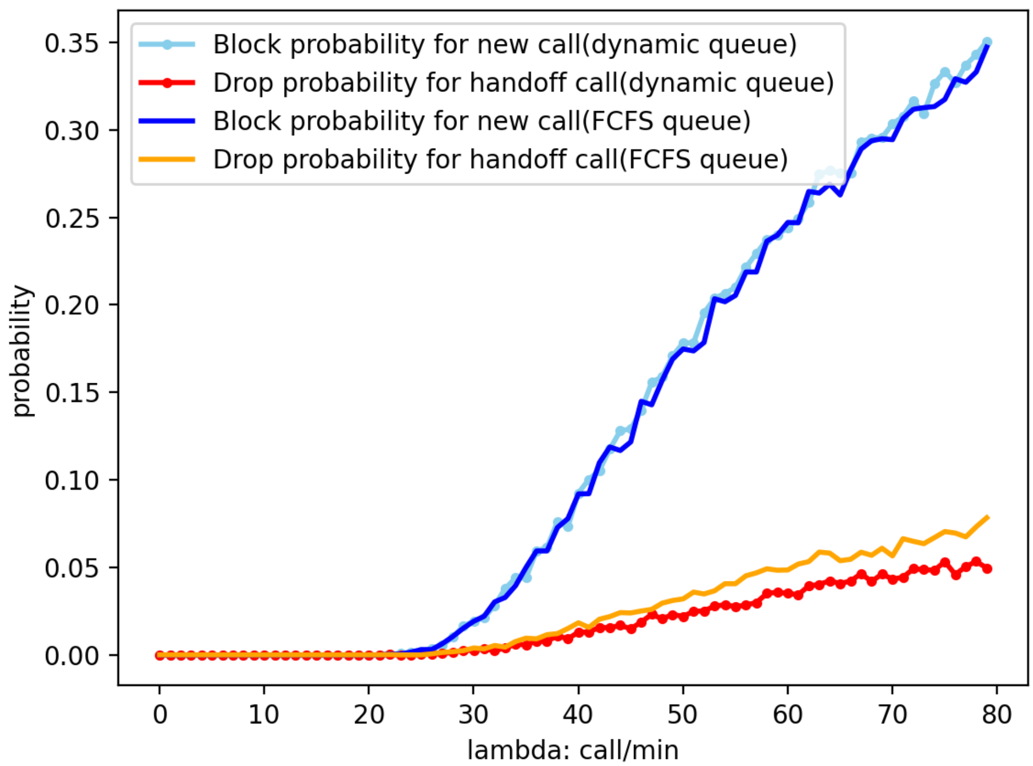
Result

For dwell time for first priority and second priority calls of 7.5, 12.5 seconds, respectively.

Paper's result:

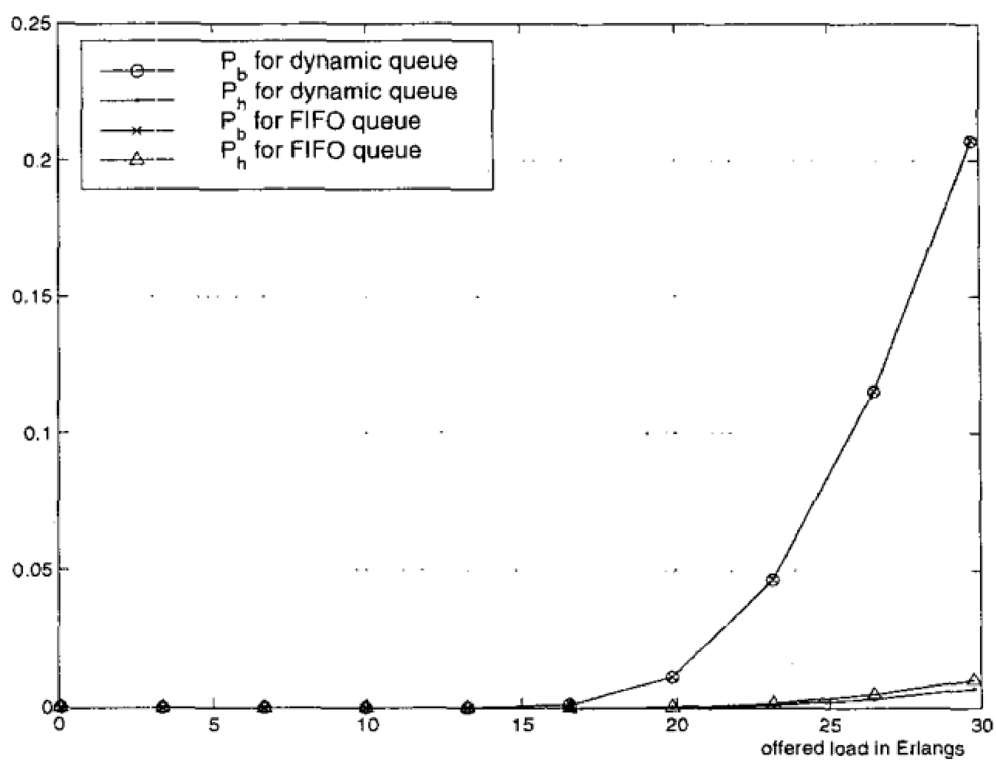


Simulation result:

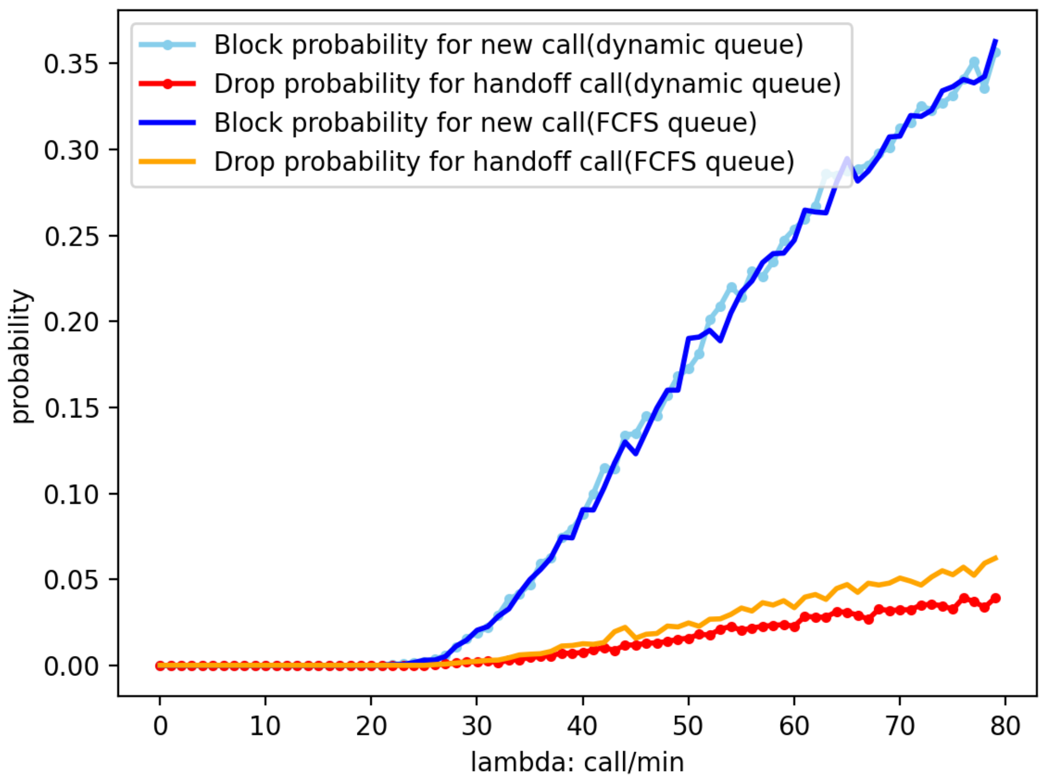


For dwell time for first priority and second priority calls of 12.5, 17.5 seconds, respectively.

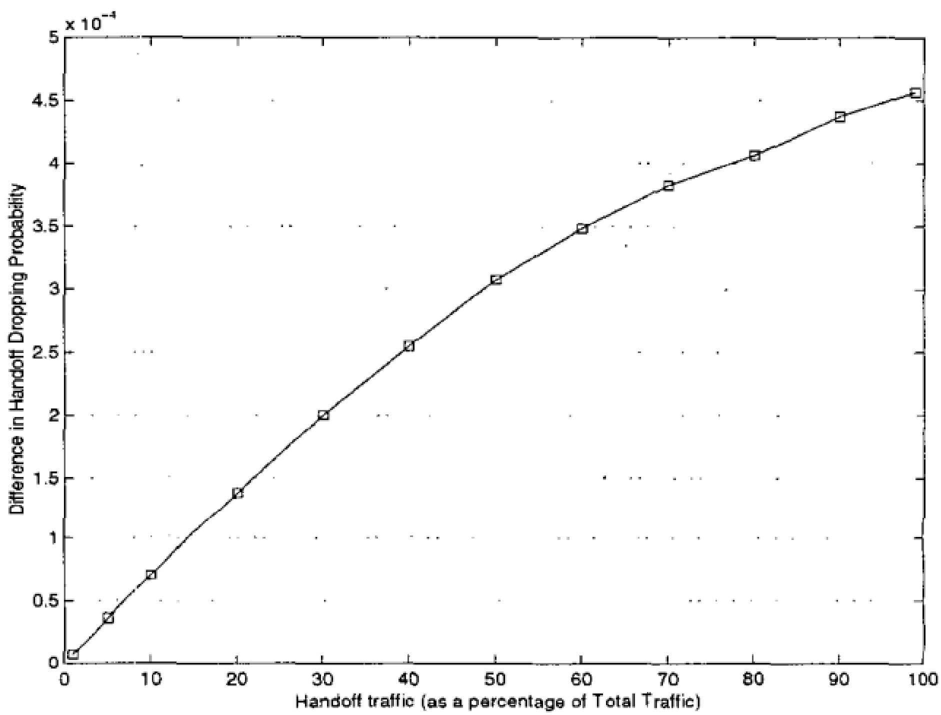
Paper's result:



Simulation result:

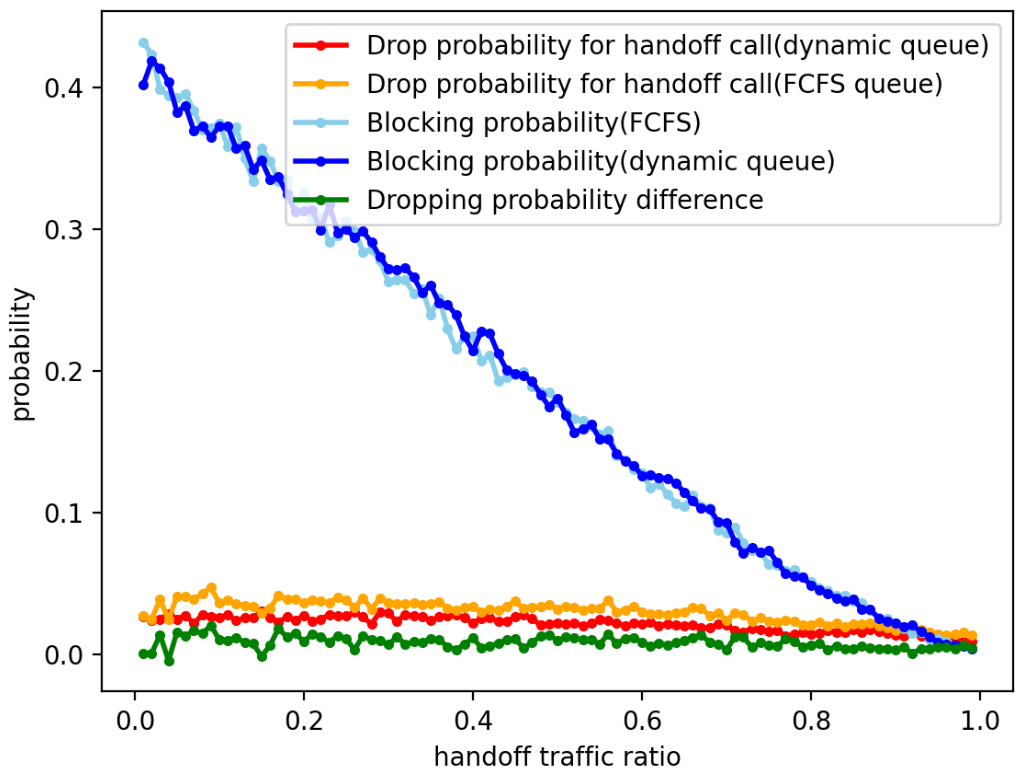


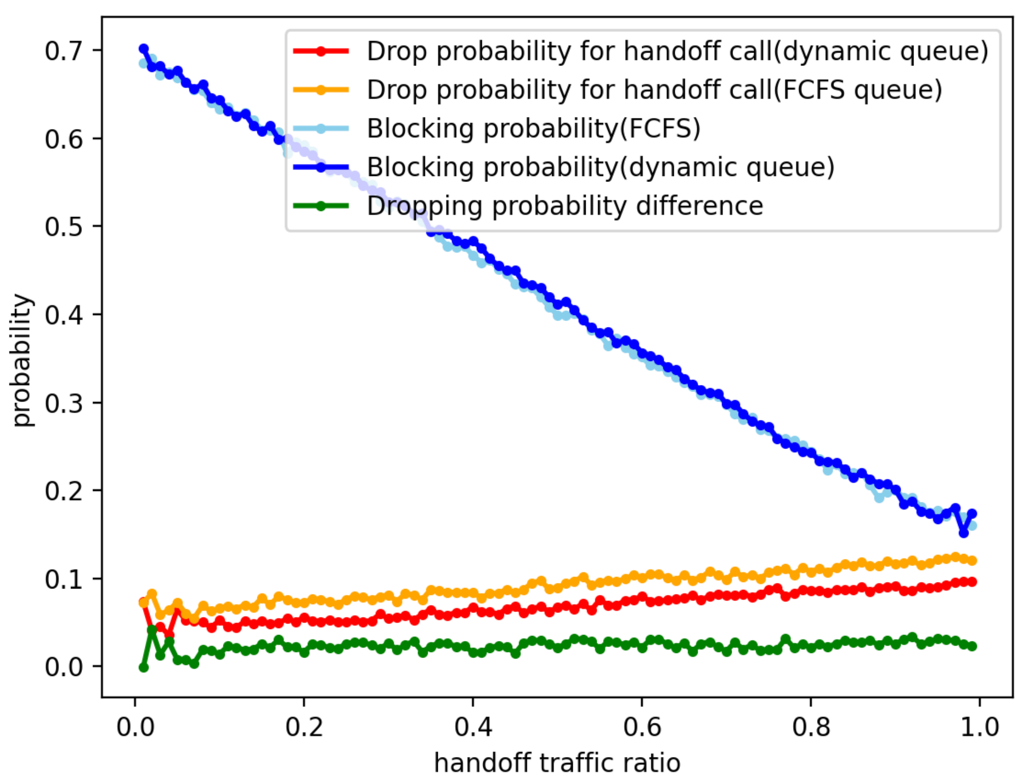
For difference in dropping probability for FCFS and Dynamic queue, Paper's result:



Simulation results

For arrival rate = 50 calls/minute(the upper one) and 100 calls/minite(the lower one):





Analysis

Dynamic queue is indeed has better performance than FIFO queue in terms of dropping probability for handoff calls, and the effect of longer dwell time indeed further lower the dropping probability for both FIFO and dynamic queue, as proposed in this paper.

As for difference in dropping probability for FCFS and Dynamic queue, the paper's graph shows that probability difference increase as the ratio of handoff traffic increase, all the way to 100%, and in the paper, the author state that, this outcome is somewhat counter intuitive, because one would expect that the difference should converge to zero as the ratio of handoff traffic increase to 100%(same reasoning for 0%).

At first, I wonder why this is the case, so I ran the simulation with different values of arrival rate, and what I have found is that, the aforementioned conclusion of this paper is indeed exists, but only exists when the arrival rate is high(see the simulation graph presented above with arrival rate equals 100calls/minute), when the arrival rate is low, the difference of dropping probability between FIFO & dynamic queue converge to 0, as expected.

I believe the reason behind this is that, when arrival rate is small, the server can handle most of the traffic, so when handoff traffic ratio is 0%, all the traffic is new calls, it either get served or blocked, the queues did not receive any traffic, so the dropping probability(which is zero) is the same for both types of queue, and when the ratio starts to increase, the queue receive traffic, and so the performance difference start to show, finally, when the ratio reaches 100%, most of the handoff calls are processed in the server, so there is little load in the queue, the dropping probability is close to zero for both types of queue.

When the arrival rate is large, the server utilization is high, so when the handoff ratio is 100%, lots of handoff traffic arrive to the queue, since dynamic queue has a better performance of handling the handoff calls, the performance difference starts to show, this describe why the dropping probability difference increase as the handoff traffic ratio increase, as presented in this paper.