Observation Period Length for Channel Selection

Yi Shi, Lei Chen(✉), Kailiang Zhang, Yuan An, and Ping Cui

Jiangsu Province Key Laboratory of Intelligent Industry Control Technology, Xuzhou University of Technology, Xuzhou 221018, China
chenlei@xzit.edu.cn

Abstract. The transmitter needs to select optimal wireless channel from several available ones in mobile communication. Since the instantaneous channel rate is time-varying with unknown statistics, the channel selection is based on observation. As the packets arrive, controller need to observe channel state in observation period, and then transmit packets through optimal channel in transmission period. We investigate the trade-off between observation period and transmission period. Short observation period might lead to wrong decision while long observation period wastes time. The simulation results show that there is an optimal length of observation period. The total transmission time experience a sharp decreasing before the optimal point. The longer observation does not cause an obvious increasing of length. This implies that the observation could be set longer rather than shorter.

Keywords: Channel selection · Scheduling policy · Wireless communication

1 Introduction

To accommodate the requests from different application scenarios, mobile communication network needs special designing for vehicle, industry and so on [1–4]. Traffic analysis is important for these special designing, some new techniques are therefore adopted to investigate the characters of network traffic [5–8]. To evaluate these network scheduling schemes, some researches focus on the effectiveness [9–11] and energy cost [12–14]. It is found that the user behaviors and service activities affect the network traffic [15], and then affect the network performance indicators [16–18]. In the future application scenarios, the most concerned performance indicators include quality of service [19–22], quality of experience [23–26], spectral efficiency [27–30] and effective capacity of channel [31–35]. Based on these researches, transmitter could choose optimal policy. However, in mobile communication, a channel observation is essential before channel selection because of the time-varying channel state. Therefore, the regret is proposed to evaluate the effective of channel selection which actually affects the schedule scheme [36–39].

The system's regret index is defined to measure the system stability [36]. In mobile communication, the real statistics of state of time-varying channel is usually unknown.

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The regret index compares the backlog with a controller select the policy based on observed statistics and the backlog under a controller that knows the best policy. This problem is known as a stochastic multi-armed bandit problem. The regret bound is drawn in [37]. Some practical policies have been studied for a long time to deal the multi-armed bandit problems [38]. Under fixed arrival rate and service rate, the boundary of regret is obtained in [39].

To reduce the regret, transmitter could evaluate the candidate channels during idle period. Through the channel estimation, transmitter can select optimal channel. The effect of channel estimations is affected by the length of idle period. In some situations, a controller begins to observe the channel state after a flow arrives in the queue. Therefore it also needs to estimate channel in busy period. A short observation period might lead to wrong decision while long observation period wastes time. In this paper, we design a simulation to explore how observation period affects the latency. In our simulation, the capacity of channel state is treated as service rate. Considering the different transmission rate between backbone network and edge network, we assume that all packets have arrived into the queue of edge network.

The paper is divided as six sections. In the second section, we give the system model. The algorithm and simulation results analysis is given in the third section. We conclude in the fourth section.

2 System Model

This channel observation problem is similar to the traditional bandit algorithms. The multi-armed bandit problem is a problem in which a fixed limited set of resources need to be allocated between alternative choices in a way that maximizes their expected gain [38]. The choice's stochastic properties are unknown at the time of allocation, and the allocation must be made under observation. As time passes, we can better evaluate the choices. However, lose time to treat the backlogged queue in transmitter. The good scheduling policy must make trade-off between observation time and dealing time. During the initial periods, we can select a candidate service to observe. When controller learns accurate channel state, we can select the optimal one. However, it is difficult to find the precise time point to stop observation. The main issue is that the it should be shorter or longer than the optimal observation time. Which policy cost more time?

In this problem, the total time T is the sum of time T_1 and time T_2. Time T_1 is the time of the test phase, which is used to count the time spent in the test period. Time T_2 means the service phase of processing packets. T can be used as the main criterion, can be written as:

$$T = T_1 + T_2 \tag{1}$$

During the period of T_1, $S_i(t)$ is the service rate of the i th server at the t th time slot which is treated as 1 with the probability u, otherwise as 0,

$$S_i(t) = \begin{cases} 1, & with\, probability \quad u \\ 0, & with\, probability \quad 1-u \end{cases}. \tag{2}$$

In this paper, the controller does not know the values of u and must therefore use observations of $S_i(t)$ to identify u_i^*. The $C_i(t)$ is defined as:

$$C_i(t) = \begin{cases} 1, \textit{the ith server is selected to test at tth time slots} \\ 0, \textit{otherwise} \end{cases}. \tag{3}$$

We assume that the controller tests u_i^* through $S_i(T)$, and $C_i(t)$ means the total number of times the server is tested in time T_1, so that the test value that is infinitely close to the true service rate can be calculated.

$$u^* = \frac{\sum_{t=1}^{T_1} S_i(t)}{\sum_{t=1}^{T_1} C_i(t)} \tag{4}$$

Then, through the u_i^*, we can choose the best server to serve the packets.

3 Simulation and Analysis

3.1 Algorithm

The algorithm we adopt in simulation is shown in Fig. 1. The algorithm uses T_1 time slots to observe the service rates of channels. In T_2 period, the channel with best service rate u_i^* observed in T_1 time slots to proceed the packets in blogged queue. The algorithms are presented as followed (Fig. 2):

```
Step1     While (queue is not empty)
Step2       If (Time < T1)
Step3         Select next channel to test;
Step4         Observe the selected channel;
Step5         Update the service rate of observed channel;
Step6         Time++;
Step7       else
Step8         Select randomly a channel from the set of servers with highest rate ;
Step9         Decide randomly whether deal with the packet according to real
              service rate;
Step10        If(the selected channel works at current time slot)
Step11          length of blogged queue --;
Step12        End if
Step13        Update the service rate of the selected channel;
Step14      End if
Step15    End while
```

Fig. 1. Simulation algorithm1

```
Step1     While (queue is not empty)
Step2       If (Time < T1)
Step3         Select next channel to test;
Step4         Observe the selected channel and processing packets ;
Step5         Update the service rate of observed channel;
Step6         Time++
Step7       else
Step8         Select randomly a channel from the set of servers with highest rate ;
Step9         Decide whether transmit the packet according to real service rate;
Step10        If(the selected channel works at current time slot)
Step11          length of blogged queue --;
Step12        End if
Step13        Update the service rate;
Step14      End if
Step15    End while
```

Fig. 2. Simulation algorithm2

3.2 Simulation Parameters

We make two simulations, the simulation parameters are listed in Table 1.

In these two simulations, we have 5 candidate channels with a service rate range from 0.3 to 0.7 similarly. Both the T_1 time increase 5 at each test from 10 to 400. Therefore, there are 79 tests in each simulation. And each test last 100 times under the fixed T_1 time.

Table 1. Simulation parameters.

Parameter name	Value of parameter in simulation 1,2
Number of data packet in blogged queue at beginning	10000
T_1 range (time slots)	[10–400]
Increasing of time slots in T_1 time range for each test	5
Number of candidate channels	5
Service rates of channel 1	0.3
Service rates of channel 2	0.4
Service rates of channel 3	0.5
Service rates of channel 4	0.6
Service rates of channel 5	0.7

3.3 Simulation Results

The simulation1 results are shown in Fig. 3 where the transmitter does not deal with the packets of blogged queue at observation period.

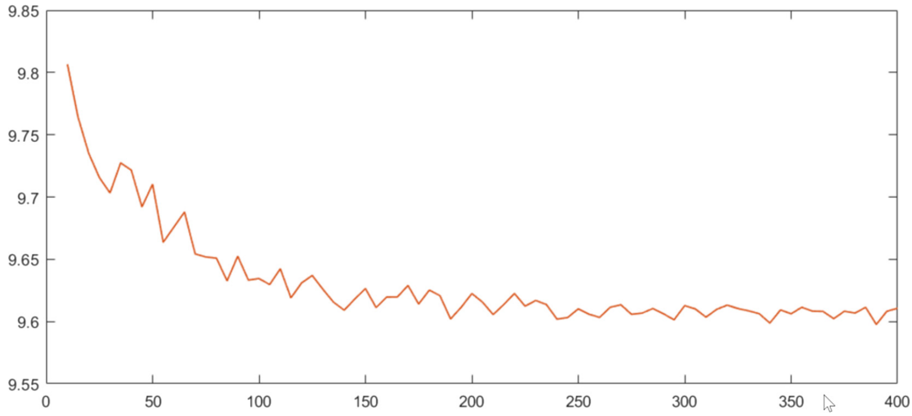

Fig. 3. Total transmission time in Simulation1 (horizontal axis unit is T1 time slot, vertical axis unit is $\ln(T_1 + T_2)$)

The simulation 2 results are shown in Fig. 4 where the transmitter send packets in blogged queue while it observes the channel state.

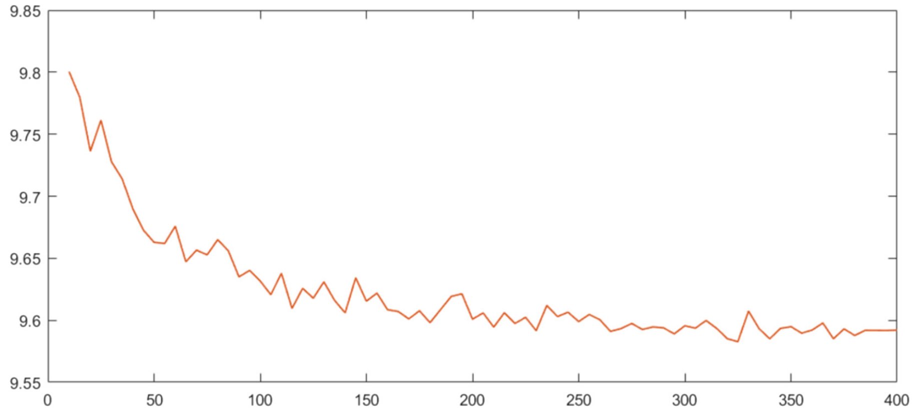

Fig. 4. Total transmission time in Simulation2 (horizontal axis unit is T1 time slot, vertical axis unit is $ln(T_1 + T_2)$)

In Fig. 3, with the increase of test period, the $ln(T_1 + T_2)$ drop down at first stage and the total transmission time gradually changes from fluctuation to stability at second stage. With the increase of T_1 time, the observed service rate becomes more accurate, so that the controller can make better decision to reduce the total time.

In Fig. 4, with the increase of period, the $ln(T_1 + T_2)$ experience a similar reducing in the test stage and the downward trend also disappear at the second stage. The total transmission time is shorter than simulation 1, because the packet processing is also carried out in T_1 time.

From these two simulations, we can know that if the test period is not sufficient the controller have no chance to observe other candidate channels in the beginning of T_2. When T_1 reaches a certain value, the controller can make optimal decision. In transmission time T_2 the controller can also observe the service rate of selected channel, and it have chance to change channel if the observed service rate drop down.

4 Conclusion

In this paper, through observing the simulation, we can find that the total dealing time decreases obviously in the early stage, and gradually becomes stable when it reaches a special point. After this point, the increase of T_1 does not cause a suddenly increase of total transmission time. Therefore, the test period should be longer in the situation that the best test time is difficult to obtain.

In practical engineering, the channel observation period can be set longer. For future research, the optimal observation should be investigated.

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