Re-configurable Traffic Aware MAC Design for Virtualized Wireless Network via Reinforcement Learning

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In this paper, they present a re-configurable MAC scheme where they showed advantages of reinforcement learning for handling traffic issues in the network by doing partitions. Device traffic statistics is used for partitioning algorithms. In the absence of such knowledge, they develop a learning algorithm using Thompson sampling to get packet arrival probabilities of devices.

1 Introduction

To improve the channel usage, the traffic statistics information could be provided to efficiently select and configure a MAC protocol adapting to the outer environment. There might not be any prior knowledge of traffic statistics. Hence, learning algorithms is difficult to use the traffic statistics such that the expected total performance is improved.

A.Motivation:
To solve issues from traditional to modern machine to machine they have focused on two things: resource allocation and isolation. In this paper, they consider a virtualized wireless network and the MAC protocol aims to preserve isolation by maintaining slice reservations.

B. Scope of the Paper and Implementation
The main contributions of this paper are described in four parts:

1. Aiming to improve the network efficiency, they design a re-configurable MAC with optimal contention-free and contention-based partition based on the device packet arrival statistics.
2. They produced an optimal output for a complex network with considerably less computational complexity as compared to the proposed CGP-based scheduling.
3. Without prior knowledge of the situation where unknown devices come, they develop a Thompson sampling-based algorithm to learn packet arrival probabilities[**2**].
4. Thompson sampling algorithm for thresholding multi-armed bandits is used for analysis[**3**].

2 Structure of the Paper

This paper is divided into following parts:

1. **System Model:**
   a) They have explained Network Model and Frame Structure for re-configurable MAC for a virtualized wireless network. By using access point for number of devices they are serving the network. As shown in Fig1 the time is divided into fixed framed structure assigned as t. This frame initializes from 'beacon' which is given by access point. After beacon it is divided into 2 parts which is DA regime and RA regime respectively. In RA regime CSMA protocol runs in which time-slot is divided into backoff units. DA regime is responsible for meeting further requirements in the devices which are delay sensitive.

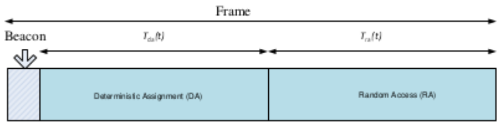

Figure 1: Time-frame in slicing

b) Initially when the time-frame *t* starts, access point decides a time-slot for allocation of DA regime then by using beacon it schedules and notifies devices. If the device having no time-slot found and having packets, it transmits into RA regime. A device having non-empty queue usually performs channel sensing in RA regime. If the sensing is found to be idle, the device send packets with probability *p* or we can called as (1-*p*). If a device is failed in transmission of packet, retransmission is restricted because it may cause error in other slices.

c) Analytical Model for p-persistent CSMA protocol in unsaturated mode and formulation for total access airtime in RA regime. For this they have given formulation for idle probability denoted as P*idle*. In virtualized wireless network, *total air time* is a performance metric which is used for calculation of isolation. They have also given formulation for total air time using P*idle*.

2. **Formulation of the Problem:** An effective slicing results in increasing efficiency and preserving isolation. An effective output is possible by switching between contention-free and contention-based schemes in a network. Contention-free regime is more effective than Contention-based as it is based on devices having higher probability in packet transmission. But it can assign to device which is having lower traffic demand hence cause system underutilization. Formulation of RA and DA regime for devices is done based on their traffic demand in time frame ‘t’ and also formulation for getting optimal solution.

3. **Scheduling with Traffic Knowledge:** For scheduling problems they set it as CGP and for complex networks they used different algorithms which is based approximation and two-step decomposition: Algorithm 1: This includes Re-configurable MAC scheduling via CGP. Here they first converted CGP problem into GP by applying monomial approximation. after that GPs can be solved separately for getting solution. Algorithm 2: Here they have mentioned ’Scalable Re-configurable MAC’ for denser network. For that they have done first solved problems based linear optimization then DC programming is done with iterative manner.

4. **Re-configurable MAC using Thompson Sampling:** They proposed algorithm for situation of transmission without prior knowledge: Algorithm 3: They have done Algorithm of Thompson Sampling for Re-configurable MAC. In the case of unknown packet arrival, this algorithm helps via passing indices of devices to the scheduler and then scheduler decides time-slot allocation. On the termination of DA regime, probabilities of unknown packet arrival is updated. Algorithm 4: Main goal of this step is to improve throughput. For that it divides packets with higher probabilities of arrival to DA regime and others are in RA regime. Development of a thresholding algorithm for the scheduling, model it as a thresholding multi-armed bandit, and apply Thompson Sampling for learning is done in this algorithm.

5. **Regret analysis:** The regret bound in the DA regime of thresholding re-configurable MAC when the network consists of one slice or number of optimal arms and Proof of TS-TMAB algorithm for binary rewards achieves an optimal regret bound is given.

3 Finding Results

1. **Simulation in MATLAB and GP problems are solved using CVX:** Results are compared using following schemes:

a) p-persistent CSMA: All devices compete with each other by performing p-persistent CSMA.

b) Random Hybrid DA-RA: ‘T*max*’ slots are assigned to the devices randomly, while the rest of devices compete in the CSMA regime with p = 0.05.

c) Distributed queuing (DQ): The frame structure is divided into three parts: i) C sub-slots for collision resolution ii) one slot for data transmission iii) one sub-slot for transmission of feedback information from AP to devices

2. **Explanation for re-configurable MAC for known data:** They considered two slices and access point in a network to note the direct effect of one slice to another. They have considered fixed parameters for executing the task.

   a) To test the isolation amongst two slices while changing one slice they continuously changed the number of devices in slice 2 and plotted the graph. Increase in N2 decreases throughput of slice 1.

   b) Using piggyback method, the device can request for new time-slot. By this, the probability of packet transmission increases and free time-slot is assigned to the device.

   c) Higher number of slices decreases the throughput because the average traffic of every slice is closed to its airtime reservation except last slice.

   d) To determine the changes in terms of isolation, they keep fixed number of devices in slice 1 changed devices in slice 2. It was found that results were not affected because the reservation of each slice were considered while scheduling.

3. **Explanation for re-configurable MAC for unknown data:** Here they considered that CSMA devices are increased as we have no information from unknown statistics. Also plotting of graph about Throughput and Delay w.r.t Time is done.

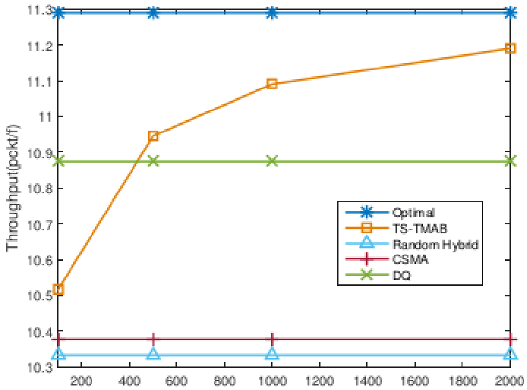

Figure 2: Throughput verses T (high load)

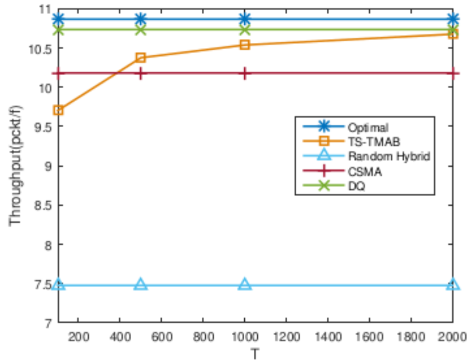

Figure 3: Throughput verses T (low load)

a) As shown in Figures 2 and 3, by increase in Time, TS-TMAB get optimum solution.

b) By observing Figures 5 and 4, it is found that T*max* leads to lower the delay.

c) Also more the packets are scheduled in DA, lesser the delay occured.

4 Conclusion

This paper presents a reconfigurable MAC, where DA and RA are used for devices with different packet transmission probabilitiesand using simulation results, the effectiveness of the algorithms for both known and unknown packet arrival statistics are proven.

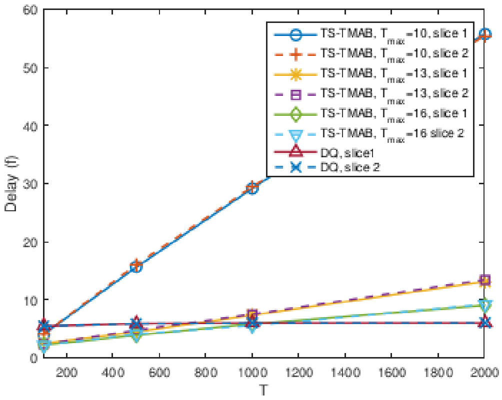

Figure 4: Delay verses T (high load)

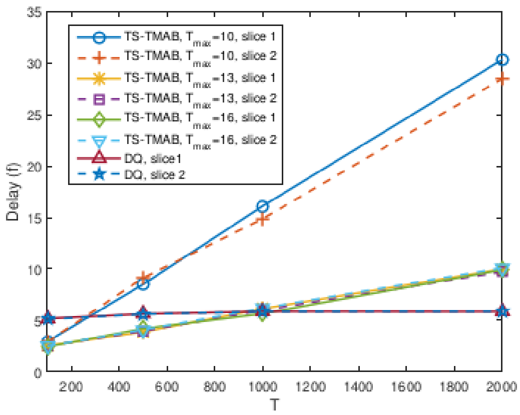

Figure 5: Delay verses T (high load)

References

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[3] S. Agrawal and N. Goyal, *Analysis of thompson sampling for the multi-armed bandit problem*. in COLT, 2012, pp. 1–39