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Congestion Control Scheme for Cognitive Radio Networks using MAQ

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Abstract

Cognitive Radio is intelligent Radio and network technology that can recognize open channels in a network spectrum and modify transmission parameters to enable maximum transmissions to occur simultaneously and thus improve the radio operation. This technology makes use of various other technologies including Adaptive Radio in which the communication system itself is responsible for modifying the performance, and Software Defined Radio (SDR) in which smart software is used in place of conventional hardware equipment like mixers, amplifiers, and modulators. This work tries to explore the issue of congestion in cognitive radio networks (CRN) and a robust mechanism to control it. A queue management algorithm called MAQ that is based on multiple model predictive control (MMPC) is built. Our main objective lies in stabilizing the TCP queue at the base station while the time-varying service capacity for secondary users (SU) causes instabilities. The proposed algorithm is confirmed by many simulations with different kinds of background traffic and configurations. This algorithm proves to be more effective than two benchmark techniques with substantial gains in every one of the situations considered.

Keywords: Active Queue Management, Cognitive Radio Networks, Multiple model predictive control, Quality of Service

1. INTRODUCTION

Technological advancements are happening in every field at a rate like never before. Most systems are dependent on wireless networks for their working. An increasing access to mobile devices and systems has set off phenomenal need for wireless network capacity which is anticipated to definitely grow in the future. Consequently, the demand for the advancement of wireless technologies is increased. It is in fact apparent from the history of evolution of wireless technologies that smart network capacities and better features are gradually adapted as progress is made in other hardware and software technologies. There is also fresh inclination and interest in Radio based architectures mainly characterized by software, which has caused technologies like cognitive Radio generate more interest. Along with these, the scarcity of wireless resources, especially spectrum, has led to the development of new approaches in wireless communication.

The Cognitive Radio (CR) technology is a result of the need to overlay the range/channel shortage. Although the terms cognitive radio and cognitive networks have become popular only recently, these are in fact a consequence of a gradual advancement of wireless technology. The emergence of these concepts however, have greatly formalized and structured the evolution of wireless networks. The concept of cognitive networks especially provides an effective solution to a lot of the challenges posed by traditional layered networks.

Looking at the cognitive radio and cognitive systems definitions, it is rather evident that the two are comparable, with the exception that smart systems have progressively broader viewpoints and likewise comprise all the system components [14]. For the future shaping of remote systems with significant uses requiring wide spectrum access and interoperability of multiple remote networks, cognitive systems are needed. Among the exceptional features of smart systems are board impedance, skilled use of remote resources, protected and safe methods of remote access and brilliant QoS [15].

Cogitive Radio is an intelligent radio and network technology that can recognize open channels in a network spectrum and modify transmission or reception parameters so that rate of transmission or reception is maximized. This technology enables both licensed and unlicensed clients to use the available spectrum. Range is designated progressively in intelligent radio systems thereby expanding the range use. The unlicensed clients can transmit in the empty range officially shared by the authorized clients with least degree of impedance. It checks the spectrum to detect the available channels and picks the best range which meets the required QoS of the unlicensed clients. The unlicensed clients leave the range when the authorized clients return. In CRNs, the authorized clients also called as primary users share the range with clients of CRN called secondary users.

1.1 Architecture of CRN

The architecture of cognitive radio networks is illustrated in the Figure 1.

Primary User: The essential client who will have the authorization to completely access a specific range band. This authorization can be controlled only by the base station and it is not influenced by the tasks of the secondary users.

Primary Base-Station: This is a fixed component which has a range permit. Originally, this station has no cognitive radio capacity in order to share the spectrum. But, the base-station may need to have cognitive radio protocols too for the cognitive clients to access the network spectrum.

Cognitive Radio User: This user will have no spectrum authorization. Thus, range access is permitted in an opportunistic way. Abilities of the secondary user comprise of range detection, range selection, range hand- off and cognitive radio MAC/routing/transport protocols among others. The client of CRN is expected to have an ability to communicate with the BS as well as with the other CRN clients.

Cognitive Radio Base-Station: This base station is also a fixed component with cognitive radio capacities. This also serves as a hub that connects the secondary users to the spectrum.

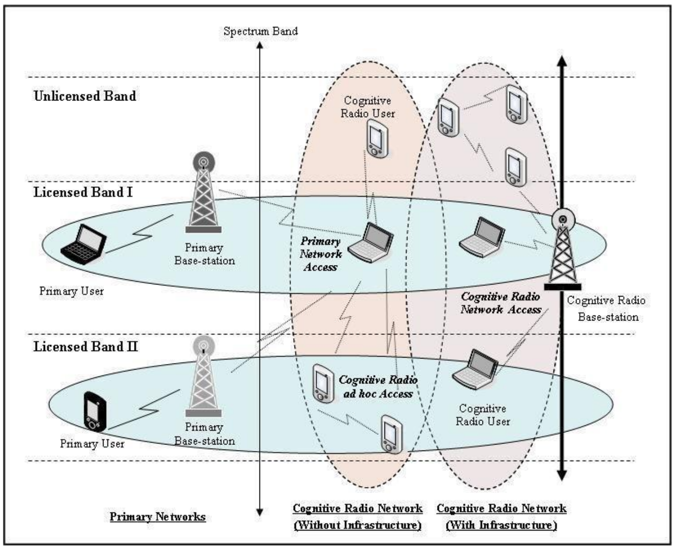

Figure 1: Architecture of CRN

2. LITERATURE SURVEY

In [1], the authors proposed a blockage or congestion control technique, named semi-TCP, for multi-bounce remote systems in light of the solicitation to send a clear value handshake.

In [2], the author proposed put forth an arrangement of lower-layers module, in which a move up to the TCP throughput could be achieved. Their work generally revolved around lowest layer structure. It doesn't deal with the fundamental issues, for instance, how to deal with the farthest point assortment as a result of PU channel obscuring and activity of channel. Major potential issue of the setup is that the model requires the exchange of visit data, which rises the transmission time significantly and huge overhead in communication is presented. In extension, the present plans do not consider the hardening of transmissions of TCP during its range recognizing period.

In [3], the authors proposed the obstacles encountered with medium access control in mm Wave wireless personal area networks (WPAN), which constitutes of directional antennas which helps navigating the high path loss that arouses in the 60GHz frequency band. The traditional CSMA/CA convention does not function admirably with directional receiving wires because of weakened bearer detecting at the transmitters. We draw conclusions as to why existing directional MAC conventions don't function admirably at 60GHz and propose an alternative directional CSMA/CA explicitly for 60GHz WPANs. Rather than depending on physical transporter detecting, the proposed convention receives virtual bearer detecting and depends on a focal organizer to disseminate arrange distribution vector (NAV) data. Both execution examination and recreation study demonstrate the fact that the proposed system causes low overhead and has hearty execution notwithstanding when the system is intensely blocked.

In [4], the authors proposed the issue of least time length connection planning for 60-GHz specially appointed remote systems utilizing directional reception apparatuses with directional shaft framing, under both traffic request and sign to impedance and clamor proportion requirements is handled. Both single-jump and multi-bounce cases are considered. For the single-ricochet circumstance, a combined entire number programming issue is point by point by solidifying a general obstacle model for directional transmissions and a Markov chain-based blockage model. Two convincing game plan counts are proposed, including a voracious count that enlarges the minute throughput for every opportunity, and a fragment age-based estimation that iteratively improves the present association plan. For the multi-hop circumstance, we develop a continuously tangled issue definition intertwining both course decision and stream assurance impediments.

In [5], authors proposed MIMO is perceived to be a up and coming innovation for 5G remote systems due to the immense potential that can improve both ghostly and vitality proficiency. In spite of the fact that the enormous MIMO framework depends on developments in the physical layer, the upper layer strategies assume significant jobs in gathering the exhibition increases of enormous MIMO. In this article, we start by investigating the pros and cons of enormous MIMO frameworks. They at that point explore the multi-layer strategies for consolidating huge MIMO in a few significant system arrangement situations.

In [6], authors have worked to give this massive multiple input multiple output (MIMO) framework has attracted immense attention regarding helping the framework throughput and result in its prices slashed. Past investigations for the most part center on time division duplexing (TDD) frameworks, which are progressively amiable to handy executions because of channel correspondence. Be that as it may, there are numerous recurrence division duplexing (FDD) frameworks sent around the world. Thusly, it is of incredible significance to explore the structure and execution of FDD huge MIMO frameworks. To lessen the overhead of direct estimation in FDD frameworks, a two- arrange pre-coding plan was as of late proposed to disintegrate the pre-coding technique into entomb bunch pre-coding. The issue of customer assembling and booking thusly rises. In their work, the makers at first propose three novel closeness measures for customer gathering subject to weighted likelihood, subspace projection, and Fubini- Study, independently, similarly as two novel gathering procedures, including different leveled and K-medoids grouping. They by then propose a one-of-a-kind customer arranging intend to further overhaul the structure throughput once the customer social affairs are molded. The pile modifying issue is seen as when very few customers are dynamic and settled with a fruitful computation. The ampleness of the proposed plans is validated with theoretical assessment and reenactments.

In [7], deduced a method in which the fundamental thought was to utilize a stochastic model. A Brownian movement pursued by Poisson process is used to anticipate the limit of the remote connection. This model does not function well in CRN in light with a fact that the variety of limit is primarily caused by the movement of essential clients, notwithstanding blurring and shadowing impacts.

In [8], the authors consider a in proposed a technique in view of the preparation model between bundle deferral and window size. In any case, the most gigantic qualification between cell framework and CRN examined in this paper is that the cell base station keeps up an alternate line for every customer (for example, each customer with a submit channel), anyway the CRN base station keeps up a typical line for all customers in our model. In this manner the major supposition in such shows does not hold and the usage of such shows in CRNs would be difficult, if positively plausible. Likewise, the range detecting period will bigly affect blockage control, which requires another CRN explicit convention structure.

In [9], the authors have proposed a stop up control that is a cross-layer, coordinating, and booking setup plot in Ad Hoc Remote frameworks. The makers characterized an advantage task issue in frameworks with fixed channels with over rate necessity and arranging objective, thereafter rotted it into three sub-issues: stop up control, coordinating, and arranging.

In [10], the authors proposed an AQM figuring, named DSM, in perspective on the mode control of discrete sliding theory. Notwithstanding the way that it oversees high repeat faltering of association limit, DSMC encounters the control over issue and it is challenging to pick up a control gain with a proper value for this estimation.

3. PROPOSED APPORACH

In this paper, a framework based on CRN is considered, in which different secondary users keep up TCP associations with different servers of TCP present in the web. The sessions have a common buffer at the base station, the last hop and bottleneck of the TCP connections which is the downlink of networks. The BS displays a size-zero reception window in the secondary users' channels in order to let the TCP senders know of the monitoring period and to freeze the servers of TCP during this time span [18]. The additive-increase-multiple-decrease (AIMD) inherent in TCP sessions do not handle a frozen period well,. The AQM model is a class of packet marking/dropping techniques executed at the router to help blockage control. Thus, we develop an AQM framework that adjusts to the queue size at the base station, which not only results in a relatively stable queue delay, but it can also absorb disturbances induced by traffic or capability change. The suggested system, known as MAQ, is based on multiple model predictive control (MMPC), which combines various model assessment and prediction with distinct weights, which can considerably improve the controller's robustness to dismiss agitating impacts from nature plan to build a different blockage control technique that can deal with such disrupting impacts.

We utilize Active Queue Management (AQM) in particular in order to deal with blockage control issue of CRN, we survey the execution of the proposed arrangement with large NS2 simulations, for instance, under both responsive and non-responsive establishment traffic, fluctuating number of TCP affiliations and distinctive disturbances. The diversion study indicates that MAQ can settle TCP support effectively in all the circumstances that we duplicated, and beats two benchmark plans with broad margins [13].

4. METHODOLGY

4.1 Cognitive Network Model

We have considered a network with *N* licensed channels. The PUs send data on these channels at standard intervals and the channels become available for SUs on the basis of a kind of on-off methodology. A main network CRN consists of a CRN base station and *M* active SUs. Cooperatively, the CRN BS and SUs sense the licensed channels to identify possibilities for SU transmission. Considering that spectrum sensing I well-studied issue, we suppose an efficient spectrum sensing system is in force and that it is highly probable that the results are precise. Figure 2 represents the infrastructure-based CRN system model.

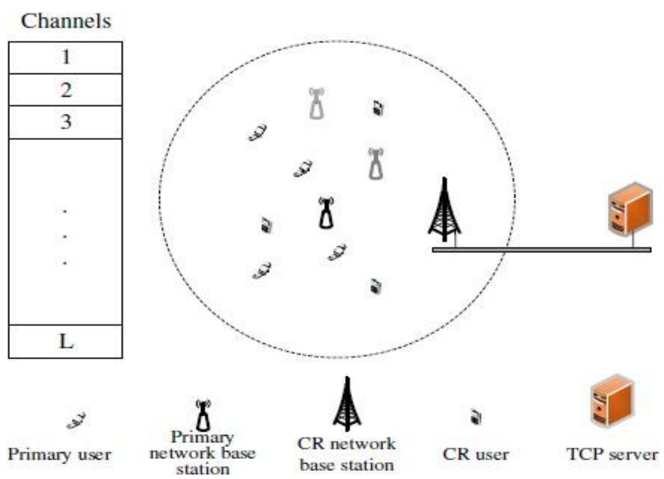

Figure 2: Network Model of the CRN

4.2 The TCP Session Model based on Fluid Flow

A fluid flow model can be used to model the dynamics of the multi-TCP system during the transmission period if the sensing period is ignored.

The working of the TCP connections that have a common queue at the base station can be obtained by making some small changes in the model.

$$\dot{W}(t) = \frac{1}{R(t)} - \beta W(t) \frac{W(t-T_p)}{R(t-T_p)} p(t-T_p)$$

$$\dot{q}(t) = \begin{cases} N(t)\frac{W(t)}{R(t)} - C(t), & q > 0 \\ \max\left\{0, N(t)\frac{W(t)}{R(t)} - C(t)\right\}, & q = 0, \end{cases}$$

4.3 Linearization and Discretization Phase

Linearization: For the proposed Multiple Model Predictive Control scheme, we initially build the model bank by selecting a number of operating points (each matching a model) and then linearizing the system around the same. The more the models, the more precise will be the depiction. However, the computational complexity will increase too. We choose π different capacity values denoted as C_i, *i = 1, 2, ..., π for* reference. A variation in the capacity will cause the queue to vary immediately. The magnitude of this relies upon how rapidly the TCP source can respond to the varying capacity. Given a normal queuing delay D_q and taking the chosen reference limits into consideration, we pick the corresponding π reference queue lengths as q_i, $i = 1, 2, ..., π$, increasingly.

Discretization: The whole system can be considered as one sample of a continuous-time model that has a finite sampling rate. Let the sampling period be denoted as T_s, which is a constant and is small enough so that each propagation delay T_p is multiple of T_s where $T_p = n_0 T_s$. The discretized system can be represented as follows:

$$x_i[k+1] = \Phi_i x_i[k] + \Gamma_i u_i[k-n_0] + \Delta_i \delta C_i(k)$$
$$y_i[k] = Q_i x_i[k] + v_i[k].$$

4.4 MAQ Design

We acquire various models for the cognitive radio congestion control system in the past section through linearization at various working points, discretization, and state enhancement. While a controller can be designed for each of the models, it is difficult to figure which of the controllers has to be active. Instead, as a model bank, we make use of the whole set of models to assess the state and performance of the scheme. The portion of the assessment is essential to our design of the control algorithm. The control output or the drop probability *p* comes into effect on the TCP server following the T_p propagation delay. When initial congestion occurs, packets are dropped at the base station from the front. The drop probability *p[k]* is calculated on the basis of measurement *q[k]* at step k. However, only after a delay in propagation will the probability *p[k]* affect the size of the queue. The structure of proposed MAQ scheme is discussed in the latter parts of this section.

Estimation Phase

In the model bank that we have created, noise is generally not recognized beforehand. Previous data must be used to predict both the augmented state as well as the result. Let *q[k]* be the length of queue at stage *k*. The Kalman Filter is used to calculate the status and performance. This algorithm operates in an iterative fashion. Using the Kalman filter, we derive the Kalman gain denoted as $KG_i(k)$.

Weights Calculation Phase

Taking the values of states and outputs of all the models, we can obtain a model that is more similar to the real system dynamics by means of probabilistic integration. Initially we gather each model's weights subject at time step *k*, signified as $\varepsilon_i[k]$. The weight is calculated by finding the difference between the actual value and the estimated output. The weights are assumed to be a Gaussian distribution and hence Bayes theorem is used to calculate the probability *p(i|k)* that *i* is actually a representation of *k*. The obtained probabilities are then normalized in order to calculate the weights. Initially, all the weights are equated to 1/π since we do not have any prior data.

Multiple Model Predictive Control Law Phase

In this phase the control law of MMPC is determined. The control signal $u_i[k]$ affects the queue size only at time $(k + n_0)$ because of the propagation delay of n_0. It is for this reason that it is essential to estimate the value of n_0 state and result beforehand. The output obtained by every model at period $(k + n_0)$ can likewise be assessed. A more precise estimate, *y,* can be calculated as a weighted average of the predicted results. The main aim is to stabilize the length of the queue with respect to the set point while maintaining the least possible difference between every control move. The first goal is clear and the reason for the second is explained in the later section. and the reason for the second is explained in the later section.

MAC Algorithm-Parameter Tuning and Analysis

In the proposed MAQ algorithm, a few parameters should be adjusted in order to begin the execution. To start with, the two weight matrices W_y and W_u in the MMPC control law phase are directly mapped to the ideal control signal. The move of control is the drop probability in range [0, 1]. But, it is essential to pick a huge value of W_u so that instability is not caused. As a rule, the bigger the ratio W_y/W_u, the further aggressive the control move. In accordance to the cognitive radio blockage control framework, we use $W_y=diag(1,1,...,1)$ and $Wu=diag(10^6,10^6,...,10^6)$, which function admirably in our research.

Secondly, taking into account, the estimation methodology, the matrix $P_i[0]$ ought to have large, diagonal values during initialization in case the covariance of state is unknown. In addition to that, the limit variations might be huge therefore and the error estimation may be higher than zero since the flow model is uncertain in nature. For this reason, the variance of disturbance O_i equated to the SD of the capacity (σ_C) and variance of output G_i is set to small value. The higher the value of the ratio O_i/G_i, the lesser the reaction time, however the bigger the overshoot (can even cause oscillation). We pick $G_i \epsilon [0.4,1]$ in our work.

In the aspect of weight computation, the coefficient λ decides the likelihood of the weights leading to an estimation error. In case of a large network with potentially large variation in parameters, a high value of λ can easily reduce the model probability $p(i|k)$ to zero. For this reason, we assign $\lambda = 1$ for our work.

We next determine the time complexity of the MAQ algorithm. For this sake, we locate the bottleneck first. The complexity of the estimation step that uses Kalman filter is linear along the estimation horizon m. The step of calculation of weight too is linear with respect to the number of models and is generally small. Hence, we can say that the most significant or the complexity determining step is the final computation of the control input. Since π is typically smaller than the estimation horizon m, it can be inferred that the time complexity is $O(m^3)$. In summary, we can say that the complexity is linear with respect to the number of models and it is cubic with respect to the estimation horizon, *i.e.*, $O(\pi m^2 + m^3)$.

4.5 Algorithm for Congestion Control

Input: Variance value (σ_C) and Average value of the service capacity (C), length of queue at a particular interval of time k

Output: The probability of drop $p[k]$ at the time period k

```
Select a number π as a model;
Map weights associated with the model as 1/π ;
The covariance of error prediction P_i and Kalman Gain KG_i is determined.
while Systems is on do
    for i = 1 : π do
        Compute the value of estimate function;
        Update value of KG_i and the value of P_i;
    for i = 1 : π do
        Update the value of probability p(i|k);
        Compute weight as w_i;
    for j = 1 : n_0 do
        Compute the value of state information;
    Minimize the value of the objective estimate and determine the analytical solution;
    Using the first element in calculated result as input, obtain p[k];
    Uniformly distributed random number is generated u(0, 1);
    if u < p[k] then
        The HOL packet is dropped from the base station
```

5. RESULTS

The Figure 3 illustrates a comparison between the proportional integral (PI) controller, and multiple model predictive congestion control is performed. The proposed algorithm enables in increase of link utilization under higher delays. The graph is plotted with Link Utilization (%) on the y-axis against Propagation Delay (ms) on the x-axis.

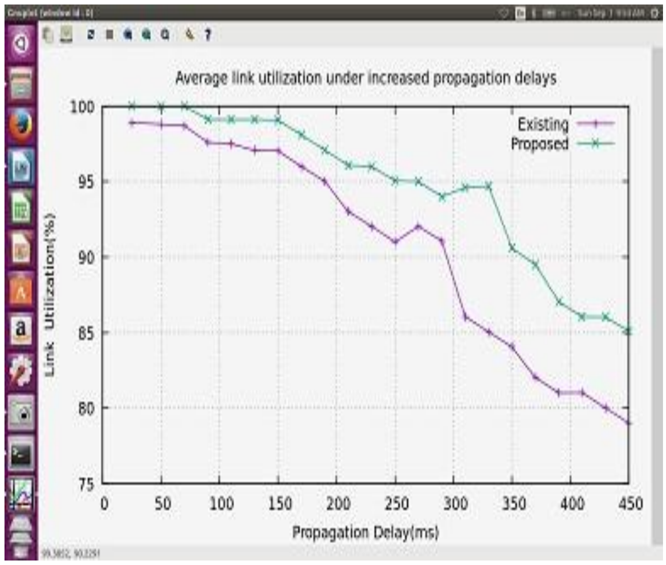

Figure 3: Average Link Utilization under Increased Propagation Delays

In the figure 4 In it can be observed that the proposed system has less queuing delay than the prior methods.

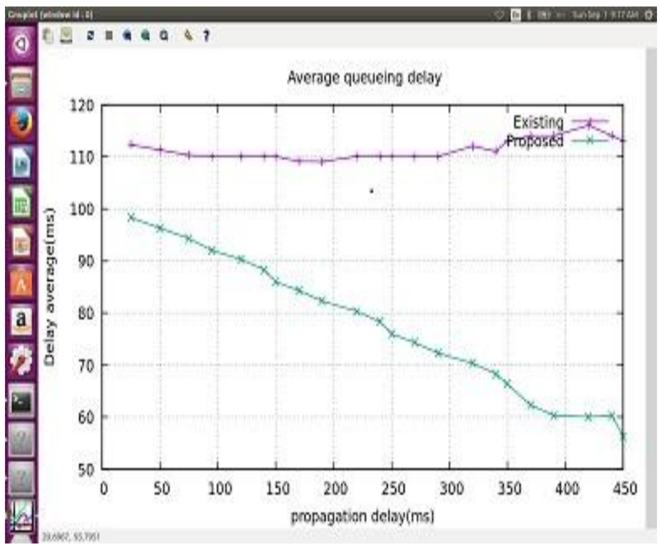

Figure 4: Average Queuing Delay under Increasing Propagation Delays Queuing delay measure for increasing propagation delays

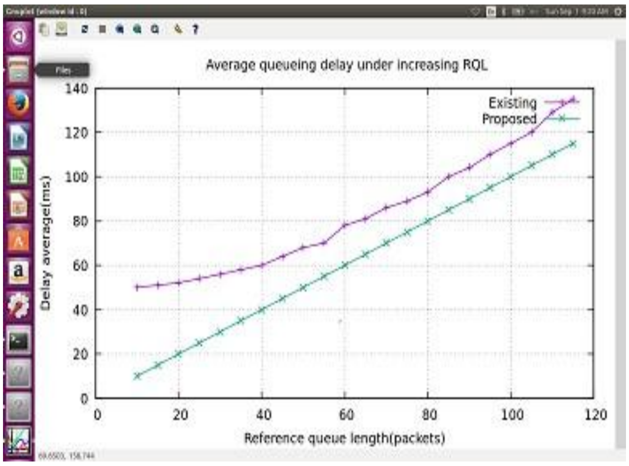

Figure 5: Average Queuing Delay under Increasing Propagation Delays

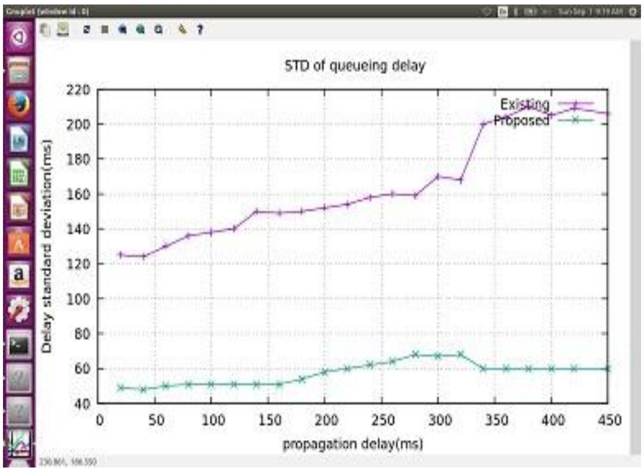

Figure 6: Average Queuing Delay under Increasing Reference Queue Lengths Under increasing reference queue lengths, STD of queuing delay

The queuing delay of our proposed scheme is lesser when compared to the other congestion algorithms. This is shown in the Figure 7

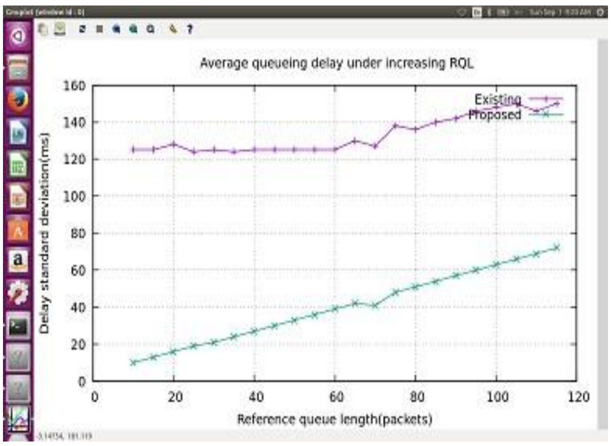

Figure 7: STD of Queuing Delay under Increasing Reference Queue Lengths

6. CONCLUSION

In the proposed work, a congestion supervision and control algorithm for the CRNs is designed and formulated. The objective we have considered here is to balance the support of TCP at the CRN base station at a wide scope regarding the infrastructure or parameters and elements. The put forth plan, named MAQ, is dependent on MMPC with upgraded input and result estimation. The proposed plan is mainly to compare our work with other major algorithms, the simulations for which have been done using NS2 under different foundation traffic categories and system/framework parameter configurations. The mechanism appeared to accomplish better execution more than two benchmark plans.

Future enhancements

In the enhancement, the parameters in the MAC layer is tuned up, the window size, SIFS, DIFS and channel assignments so that the data processing rate increases and achieves higher data delivery ratio and less delay.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

The research is performed by the authors and individuals' contributions are provided is as follows: Experimental work, Testing, Paper writing, characterization, conceptualization, methodology, Implementation.

REFERENCES

1. Y. Cai, S. Jiang, Q. Guan, and F. R. Yu, "Decoupling congestion control from tcp (semi-tcp) for multi-hop wireless networks", EURASIP Journal on Wireless Communications and Networking, vol. 2013, no. 1, p. 149, 2013. 46 Bibliography
2. J. Wang, A. Huang, and W. Wang, "Tcp throughput enhancement for cognitive radio networks through lower-layer configurations", in 2012 IEEE 23rd International Symposium on Personal, Indoor and Mobile Radio Communications- (PIMRC). IEEE, 2012, pp. 1424–1429.
3. M. X. Gong and S. F. Midkiff, "Distributed channel assignment protocols: a crosslayer approach [wireless ad hoc networks]",in IEEE Wireless Communications and Networking Conference, 2005, vol. 4. IEEE, 2005, pp. 2195– 2200.
4. Z. He, S. Mao, and T. T. S. Rappaport, "On link scheduling under blockage and interference in 60-ghz ad hoc networks", IEEE Access, vol. 3, pp. 1437–1449, 2015.
5. Q. Gao, K. Jin, S.-H. Ying, Y. Zhang, G. Xiao, Y. Shang,

Z. Duan, X. Hu, X.- Q. Xie, G. Zhou et al., "Genome sequencing and comparative transcriptomics of the model entomopathogenic fungi metarhizium anisopliae and m. acridum", PLoS genetics, vol. 7, no. 1, p. e1001264, 2011.

6. C. Jack, R. C. Petersen, Y. C. Xu, P. C. O'Brien, G. E. Smith, R. J. Ivnik, B. F. Boeve, S. C. Waring, E. G. Tangalos, and E. Kokmen, "Prediction of ad with mribased hippocampal volume in mild cognitive impairment", Neurology, vol. 52, no. 7, pp. 1397–1397, 1999.

7. K. Winstein, A. Sivaraman, and H. Balakrishnan, "Stochastic forecasts achieve high throughput and low delay over cellular networks",in Presented as part of the 10th {USENIX} Symposium on Networked Systems Design and Implementation ({NSDI} 13), 2013, pp. 459–471.

Y. Zaki, T. P¨otsch, J. Chen, L. Subramanian, and C. Gorg, "Adaptive congestion control for unpredictable cellular networks", in ACM SIGCOMM Computer Communication Review, vol. 45, no. 4. ACM, 2015, pp. 509–522.

8. S. Floyd and V. Jacobson, "Random early detection gateways for congestion avoidance", IEEE/ACM Transactions on networking, no. 4, pp. 397–413, 1993.

9. A. Kumar and K. G. Shin, "Managing tcp connections in dynamic spectrum access based wireless lans", in 2010 7th Annual IEEE Communications Society Conference Dept. of CSE, UVCE 2018-2019 47 Bibliography on Sensor, Mesh and Ad Hoc Communications and Networks (SECON). IEEE, 2010, pp. 1–9.

10. K. Nichols and V. Jacobson, "Controlling queue delay, Queue", vol. 10, no. 5, p. 20, 2012.

11. S. Kunniyur and R. Srikant, "End-to-end congestion control schemes: Utility functions, random losses and ecn marks", IEEE/ACM Transactions on Networking (TON), vol. 11, no. 5, pp. 689–702, 2003.

12. H. A. B. Salameh, M. Krunz, and D. Manzi, "Spectrum bonding and aggregation with guard-band awareness in cognitive radio networks", IEEE Transactions on Mobile Computing, vol. 13, no. 3, pp. 569–581, 2013.

13. K. Xiao, S. Mao, and J. K. Tugnait, "Congestion control for infrastructure-based crns: A multiple model predictive control approach", in 2016 IEEE Global Communications Conference (GLOBECOM). IEEE, 2016, pp. 1–6.

14. V. Misra, W.-B. Gong, and D. Towsley, "Fluid-based analysis of a network of aqm routers supporting tcp flows with an application to red", in ACM SIGCOMM Computer Communication Review, vol. 30, no. 4. ACM, 2000, pp. 151–160. Dept. of CSE, UVCE 2019 48