GCC over Heterogeneous Wireless Ad hoc Networks

M.Rajesh[1*], J.M Gnanasekar [2]
[1]Research Scholar, Department of Computer Science & Engineering, St.Peter's University Chennai, India
[2]Professor & Head Department of Computer Science & Engineering2, KarpagaVinayaga College of Engineering & Technology,
***Corresponding author:rajesmano@gmail.com; jmg_sekar@yahoo.com**

ABSTRACT

Congestion control in wireless networks has been extensively investigated over the years and several schemes and techniques have been developed, all with the aim of improving performance in wireless network. With the rapid expansion and implementation of wireless technology it is essential that the congestion control problem be solved. This paper we propose to control the congestion and error in network using Forward Error Correction (FEC) technique, which will avoid the error. Hybrid Resource based Congestion Control (HRCC) which will reduce congestion in transmission channels and show that a combination of queue-length-based scheduling at the base station and congestion control implemented either at the base station or at the end users can lead to fair resource allocation, queue-length stability and reduce congestion in transmission channels.

Keywords: Congestion; Forward Error Correction; Hybrid Resource based Congestion Control; resource allocation**.**

INTRODUCTION

Congestion control in a TCP/IP (Transmission Control Protocol/Internet Protocol) based internet is complex and challenging (Zhiqiang Shi, 2013) and over the years a lot of effort and resources have been dedicated to the research in this area. TCP provides only end-to-end flow control and relies on packet loss as an indicator of congestion (D. Miorandi, 2008; M. Haenggi, 2008). On the other hand, IP is a connectionless stateless protocol and has no provision for any mechanism to detect or control congestion.

TCP limits a sender's transmission rate relative to the network congestion such that if there is little congestion on the path between sender and receiver then the transmission rate will increase, otherwise if there is congestion, the transmission rate will decrease. TCP employs a window-based scheme to control the trans-mission rate and the size of the window directly limits the transmission rate. With TCP, congestion is avoided by changing the window size which greatly impacts the transmission rate. Generally with most TCP versions used in the Internet today, if there is little or no congestion, the window size increases by some factor to the predefined size called the slow start threshold, ss thresh (Slow Start Threshold). After attaining the ssthresh size, the window size increases linearly. If a packet is lost or congestion is detected, the window size is de-creased significantly to allow the network to recover from congestion.

The widely used standard TCP congestion control approach worked well for wired networks since loss of a packet was in most instances due to the congestion in the network. But with the rapid explosion of wireless networks, there is a significant increase in the number of combined wired and wireless networks and congestion control mechanisms previously used for wired networks do not perform well in the wireless links and wireless networks. The main reason for this decrease in performance of the widely used TCP congestion control mechanisms is that for wireless networks packet loss is caused frequently by several factors other than congestion such as noisy channels or fading radio signals, interference, host mobility and disconnection due to limited coverage (K. Huang, 2009). The current TCP mechanisms cannot distinguish congestion due to wireless fading channels or bandwidth reduction and therefore make unnecessary reduction in the congestion window size and cause severe performance degradation (P. C. Pinto, 2009).

Significant efforts and resources have been utilized in researching and developing techniques that would enhance performance in the wireless portion of wired-wireless networks. Two studies show that accurate estimation of the available bandwidth for ssthresh calculation and setting greatly improves performance. An-other study indicates that effectively manipulating the size of the window is essential in improving performance. A combination of both bandwidth calculation and window manipulation is proposed in to improve performance.

Hybrid resource based congestion control: Our proposed Hybrid Resource-Based End-To-End Control Protocol (HRCC) is aimed to work around the optimal point in the sense that the channel capacity is fully utilized while no congestion is caused. As mentioned earlier, in mobile ad hoc networks, the optimal window size for TCP is very small, typically less than 5 in packets and even less than 1. Hence any change in congestion window may result in large throughput oscillation in each RTT (Round Trip Time), failing to stabilize the throughput. For this reason, HRCC, unlike TCP, employs rate based control, in order to stabilize the throughput of each flow while making full use of the available bandwidth.

Protocol Overview: HRCC controls the sending rate of each flow by the explicit feedback carried in the ACKs. And each HRCC packet carries a congestion header as shown in Table II, which is used to communicate a flow's state to intermediate nodes and the feedback from the intermediate nodes further to the destination. The field rp is the sender's current permit arriving rate, and the field ci is the sender's currently used control interval. They are filled in by the sender and never modified in transit. The last field, fb, is initiated by the sender and all the intermediate nodes along the path may modify it to directly control the packet sending rate of the sources.

The HRCC sender maintains an estimate of the round trip time rtt and accordingly calculates the control interval ci. It also adjusts the permit arriving rate rp according to the explicit feedback in the ACKs. Each time the sender transmits a packet, it attaches a congestion header to the packet with the latest rp and ci. All the nodes along the flow's path, including the HRCC sender and receiver, keep monitoring the channel busyness ratio rb, and calculate the feedback accordingly. Then, according to the rules specified in 5.3, the node will decide whether and how to modify the fb field in the congestion header. The more congested node later in the path can overwrite the fb field in the congestion header. Ultimately, the packet will contain the feedback from the bottleneck node along the path. When the feedback reaches the receiver, it is returned to the sender in an ACK packet, and the sender updates its permit arriving rate rp accordingly. The updated arriving rate rp is then used by the sender to control the permit arriving rate at the leaky bucket.

Related work: The work in (J. Kim, 2010; S. Shin and H. Schulzrinne, 2009) provides a utility-based optimization framework for Internet congestion control. The same framework has been applied to study the congestion control over ad hoc wireless networks (Q. Xue and A. Ganz, 2003). In (M. Haenggi, 2008), the authors study joint congestion control and media access control for ad hoc wireless network, and formulate rate allocation as a utility maximization problem with the constraints that arise from contention for channel access. This paper substantially extends to include routing and to study the network with time-varying channel and multi rate devices. In (S. Shah and K. Nahrstedt, 2002), the authors use multi-commodity flow variables to characterize the network capacity region for a wireless network with time-varying channel, and propose a joint routing and power allocation policy to stabilize the system whenever the input rates are within this capacity region. In (M. Haenggi and R. K. Ganti, 2009), the authors study the impact of interference on multi-hop wireless network performance. They model wireless interference using the conflict graph, and show that there is an opportunity for achieving throughput gains by employing an interference aware routing protocol. We use the same construction to model the contention relations among wireless links. In (P. C. Pinto, 2009; F. Wang, 2008), the authors use a similar model to study the problem of jointly routing the flows and scheduling the transmissions to determine the achievable rates in multi-hop wireless networks. All these works focus on the interaction between link and network layers, and try to characterize the achievable rate region at network layer. We include the end-to-end transport layer, and as such, the network uses congestion control to automatically explore the achievable rate region while optimizing some global objective for the end users. The stochastic Lyapunov function method is a powerful tool to prove the stability of Markovian system (L. Tassiulas and A. Ephremides, 1992). Especially, Theorem 3.1 in ((L. Tassiulas and A. Ephremides, 1992) provides sufficient conditions for the stability of general Markov chain. We combine convex analysis with stochastic Lyapunov method to establish the stability and optimality properties of networks with time-varying channels. Our result is applicable to a variety of time-varying systems that can be solved or modeled by dual algorithms. Similar result is obtained in other contexts through different techniques.

Our goal is to present a systematic approach to cross-layer design, not only to improve the performance, but more importantly, to make the interactions between different layers more transparent. Motivated by the duality model of TCP/AQM, which is an example of "horizontal" decomposition via dual? Decomposition, researchers have extended the utility maximization framework to provide a general cross-layer design methodology. As we will see in this paper, duality theory leads to a natural "vertical" decomposition into separate designs of different layers that interact through congestion price. Recent publications along this line of "layering as optimization decomposition" includes, for TCP/IP interaction, for routing and resource allocation, for TCP and physical layer, and for joint TCP and media access control or scheduling.

Model: Consider an ad hoc wireless network with a set N of nodes and a set L of logical links. These links are directed, though we assume connectivity to be symmetric, i.e., link (j, i) ∈ L if and only if (i, j) ∈ L. We assume a static topology and each link l has a fixed finite capacity cl bits per second when active, i.e., we implicitly assume that the wireless channel is fixed or some underlying mechanism is used to mask the channel variation so that the wireless channel appears to have a fixed rate. This assumption will be relaxed in Section V.

Wireless channel is a shared medium and interference-limited where links contend with each other for exclusive access to the channel. We will use the conflict graph to capture the contention relations among links. The feasible rate region at link layer is then a convex hull of the corresponding rate vectors of independent sets of the conflict graph. We will further introduce multi-commodity flow variables, which correspond to the link capacities allocated to the flows towards different destinations, to describe the rate constraint at network layer. The resource allocation is then formulated as a utility maximization problem with schedulability and rate constraints.

Performance evaluation: Most congestion control schemes used NS2 simulations to evaluate their performance except for where experiments were performed by modification of Linux Kernel 2.6.7. Commonly used performance metrics were employed in both the simulations and experiments and include error rate, bandwidth, link capacity, number of connections and rtt length, fairness and friendliness. It shows metrics used in each scheme. The percentage increase in throughput compared to the standard TCP congestion control technique implemented in the Internet is presented in Table 3. Various levels in improvement in throughput were observed for all schemes, ranging from 10% to 550%. Due to the lack of commonality amongst the compared metrics it was generally impossible to compare techniques against each other to determine the best algorithm. However, all techniques compared their improve performance against the TCPW and the results are presented in Figure-1Overall, the TCP constant, TCP-TP and TCP-EVBWE all out perform TCPW in various network scenarios.

Fairness and friendliness are important metrics in evaluating the performance of a scheme. Fairness means that all similar connections have the same opportunity to transfer data and that one connection would not aggressively consume resources at the expense of other connections such that connections with longer round trip times are not at a disadvantage. Friendliness is that connections of different schemes are able to co-exist.

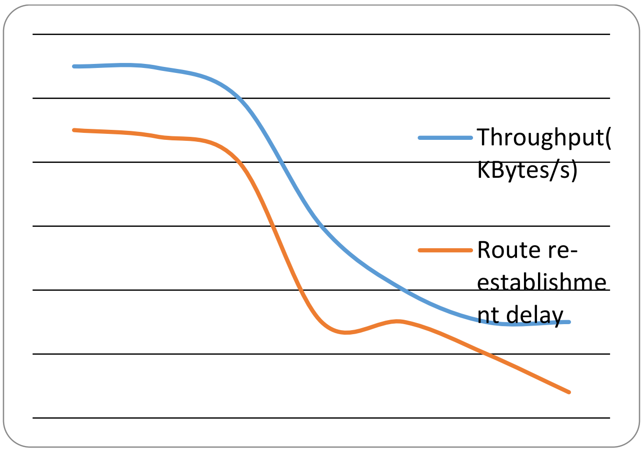

Figure.1.Throughput (Mbps) comparison in wireless networks with varying packet round trip times.

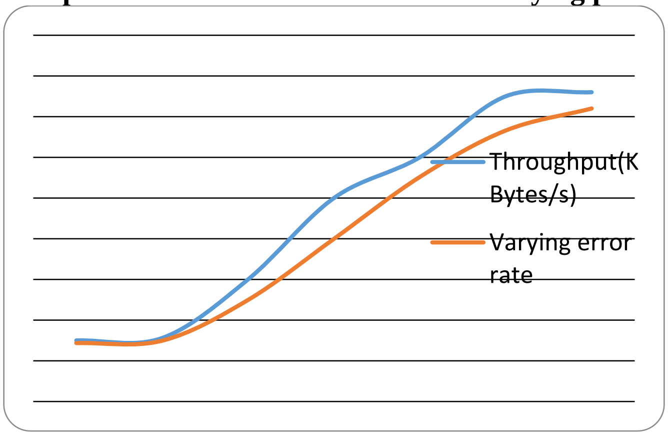

Figure.2.Throughput (Kbps) variation with varying error rates.

Simulation Parameters: For our experiments, we used a fixed packet size of 200 bytes and data rate of 12.8 Kbps (on the wireless channels), which are reasonable values for wireless networks. The number of hops between the source and destination is set to 10 and the corresponding window size is 4 Kbytes (20 packets). We have assumed that the network in our simulation does not suffer from congestion. Consequently, any packet loss is attributed to route failure only. The input parameters to the simulation are the failure rate and route reestablishment delay each run of the simulation is for a period of 100 seconds and is repeated 10 times. The averages of the ten values are reported.

The simulation is event-driven and proceeds as follows: Transmission of a packet leads to a SEND event at the source which in turn triggers an ACK event and a TIMEOUT event. The timestamp of the ACK event is calculated as follows: tACK = tSEND + delay based on number of hops, data rate and packet size + random variance (of up to 10% of total time to account for packet delays). The timestamp of the TIMEOUT event is based on TCP's timeout estimation mechanism. Depending on the conditions as described below, one of the above events (ACK/TIMEOUT) will be valid and the other event is then discarded. In order to simulate the reconfiguration of the network due to mobility, route failure events are periodically generated. The route is re-established after a delay corresponding to the RRD. Based on the current time instant, location and duration of the failure and the timestamp of a SEND event, we can determine whether a packet reached the destination successfully and if an ACK successfully reached the source. Once we have determined which packets is \lost," their ACK events are then deleted from the event queue. Over this model, we implemented basic TCP and the proposed TCP-F. We then ran the simulation for both cases using different values of failure interval and route re-establishment delay (RRD). It was ensured that both TCP and TCP-F were simulated under the same conditions.

In Fig. 1, we see that as the sequence number of received Packets is smoothly increasing, each GCC flow has a stable throughput, and almost no packet needs to be retransmitted. Here the instantaneous throughput of a flow can be calculated by taking derivative of the sequence number with respect to time, i.e., the slope of the curve in Fig. 4 (c). This further verifies that GCC almost does not drop packets due to MAC collision or buffer overflow. On the contrary, TCP frequently retransmit lost packets. For clear demonstration, we only present the result from the start of the transmission, namely 10s, to 50s, although we observe the similar phenomenon for the rest of the simulation. As a result, the throughput of GCC is 12.8% higher than that of TCP Fig. 2 shows that GCC maintains a much smaller queue size at all the nodes than TCP. In fact, the average queue size of GCC is always smaller than 1. This translates into a short end-to-end delay for GCC, which is only 1/9 of that of TCP, as shown in Table III. In addition, as pointed out earlier, a large queue size keeps node busy with contending the channel, which increases contention and causes packets to be dropped. Thus, a small queue size is desirable. This also explains why TCP has a much larger packet dropping rate (in packets/s) than GCC. We also simulate the same topology with the AODV routing algorithm. As seen in Table III, the aggregate TCP throughput drops 37% compared with the case where the pre-computed shortest path is used. However, the aggregate GCC throughput only drops 12%. As a result, in this case, the aggregate throughput of GCC is 57% higher than that of TCP.

CONCLUSION

We have presented a model for the joint design of congestion control, routing and scheduling for ad hoc wireless networks by extending the framework of network utility maximization and applying dual-based decompositions. We formulate resource allocation in the network with fixed wireless channels or single-rate wireless devices as a utility maximization problem with schedulability and rate constraints arising from contention for the wireless channel. By dual decomposition, we derive a sub gradient algorithm that is not only distributed spatially, but more interestingly, decomposes the system problem vertically into three protocol layers where congestion control, routing and scheduling jointly solve the network utility maximization problem. We also extend the dual algorithm to handle the network with time-varying channel and adaptive multi-rate devices, and surprisingly show that, despite stochastic channel variation, it solves an ideal reference system problem which has the best feasible rate region at link layer.

Dual algorithms for convex optimization formulations of generalized network utility maximization have found many applications recently for both deterministic and connection level stochastic models. We show that, for a large class of such convex optimization problems, stability and average performance are not affected by channel-level stochastic models.

GCC provides a general technique to carry out optimization based network designs in a time-varying environment. Further research steps stemming out of this paper include the following. First, unique features in our algorithm for practical implementations need to be further leveraged. Second, we will extend the results to networks with more general interference models and/or node mobility. Third, scheduling problem is always a challenging problem for ad hoc network, and continued exploration of distributed scheduling protocols will further enhance the performance gain from cross-layer design involving link layer. Fourth, we will formally quantify the interesting observation that channel variations in fact help mitigate the overall system's degradation due to suboptimal design in one layer.

REFERENCES

A. L. Stolyar, Maximizing queueing network utility subject to statbility: greedy primal-dual algorithm, Queueing Systems, 50(4), 2005, 401-457.

A. L. Stolyar, MaxWeight scheduling in a generalized switch: state space collapse and workload minimization in heavy traffic, Ann. Appl. probab., 14(1), 2004, 1-53.

A. Rabbachin, T. Q. S. Quek, H. Shin, and M. Z. Win, Cognitive network interference, IEEE J. Sel. Areas Commun., 29(2), 2011, 480–493.

C. E. Perkins and E. M. Royer, Ad-hoc on-demand distance vector routing, WMCSA, Febuary 1999.

C. H. Papadimitriou and K. Steiglitz, Combinatorial Optimization: Algorithm and Complexity, Dover Publications, 1998.

C. So-In, R. Jain, and A.-K. Tamimi, Scheduling in IEEE 802.16e Mobile WiMAX Networks: Key Issues and a Survey, IEEE J. Selected Areas in Comm., 27(2), 2009, 156-171.

D. Miorandi, E. Altman, and G. Alfano, The impact of channel randomnesson coverage and connectivity of ad hoc and sensor networks, IEEE Trans. Wireless Commun., 7(3), 2008, 1062–1072.

F. Baccelli and B. Blaszczyszyn, Stochastic geometry and wireless networks volume 2: applications, Found. Trends Netw., 4(1-2), 2009, 1–312, 2009.

F. Wang, A. Ghosh, C. Sankaran, P. Fleming, F. Hsieh, and S. Benes, Mobile WiMAX Systems: Performance and Evolution, IEEE Comm. Magazine, 46(10), 2008, 41-49.

H. Badis and K.A. Agha, QOLSR, QoS Routing for Ad Hoc Wireless Networks Using OLSR, European Trans. Telecomm., 16(5), 2005, 427-442.

I. Stanojev, O. Simeone, Y. Bar-Ness, and D. Kim, On the energy efficiency of hybrid-ARQ protocols in fading channels, in Proc. 2007 IEEE ICC.

J. Kim, H. Jin, D. K. Sung, and R. Schober, Optimization of wireless multicast systems employing hybrid-ARQ with Chase combining, IEEETrans. Veh. Technol., 59(7), 2010, 3342–3355.

J. Wang, L. Li, S. H. Low and J. C. Doyle, Cross-layer optimization in TCP/IP networks, IEEE/ACM Trans. on Networking, June 2005.

K. Huang, V. K. N. Lau, and Y. Chen, Spectrum sharing between cellular and mobile ad hoc networks: transmission-capacity trade-off, IEEE J. Sel. Areas Commun., 27(7), 2009, 1256–1267.

L. Tassiulas and A. Ephremides, Stability properties of constrained queueing systems and scheduling policies for maximum throughput in multihop radio networks, IEEE Trans. on Automatic Control, 37(12), 1992, 1936-1948.

M. Andrews and L. Zhang, Satisfying Arbitrary Delay Requirements in Multihop Networks, Proc. IEEE 27th Conf. Computer Comm., 116-120, 2008.

M. Haenggi and R. K. Ganti, Interference in large wireless networks, Found. Trends Netw., 3, 2009, 127–248.

M. Haenggi, A geometric interpretation of fading in wireless networks: theory and applications, IEEE Trans. Inf. Theory, 54(12), 2008, 5500–5510.

M. Haenggi, J. G. Andrews, F. Baccelli, O. Dousse, andM. Franceschetti, Stochastic geometry and random graphs for the analysis and design of wireless networks, IEEE J. Sel. Areas Commun., 27(7), 2009, 1029–1046.

M. Wattenhofer and R. Wattenhofer, Distributed weighted matching, 18th DISC, (Ed., R. Guerraoui) LNCS 3274, Springer, 2004.

N. Z. Shor, Monimization Methods for Non-Differentiable Functions, Springer-Verlag, 1985.

P. C. Pinto, A. Giorgetti, M. Z. Win, and M. Chiani, A stochastic geometry approach to coexistence in heterogeneous wireless networks, IEEE J. Sel. Areas Commun., 27(7), 2009, 1268–1282.

Q. Xue and A. Ganz, Ad Hoc QoS On-Demand Routing (AQOR) in Mobile Ad Hoc Networks, J. Parallel and Distributed Computing, 63(2), 2003, 154-165.

R. Preis, Linear time 1/2-approximation algorithm for maximum weighted matching in general graphs, 16th STACS, (Eds., C, Meinel and S. Tison), LNCS 1563, Springer, 1999.

R. Uehara and Z. Chen, parallel approximation algorithms for maximum weighted matching in general graphs Inf. Proc. Letter, 76, 2000, 13-17.

S. Ganguly, V. Navda, K. Kim, A. Kashyap, D. Niculescu, R. Izmailov, S. Hong, and S. Das, Performance Optimizations for Deploying VoIP Services in Mesh Networks," IEEE J. Selected Areas in Comm., vol. 24, no. 11, pp. 2147-2158, Nov. 2006.

S. Shah and K. Nahrstedt, Predictive Location-Based QoS Routing in Mobile Ad Hoc Networks," Proc. IEEE Int'l Conf. Comm., 2(2002), 1022-1027.

S. Shin and H. Schulzrinne, Measurement and Analysis of the VoIP Capacity in IEEE 802.11 WLAN, IEEE Trans. Mobile Computing, 8(9), 2009, 1265-1279.

S. Weber, J. G. Andrews, and N. Jindal, An overview of the transmission capacity of wireless networks, IEEE Trans. Commun., 56(12), 2010, 3593–3604.

V. Chandrasekhar and J. G. Andrews, Uplink capacity and interference avoidance for two-tier femtocell networks, IEEE Trans. Wireless Commun., 8(7), 2009, 3498–3509.

X. Wang and K. Kar, Cross-Layer Rate Control for End-to-End Proportional Fairness in Wireless Networks with Random Access, Proc. ACM MobiHoc, 2005.

Y. Hwang and P. Varshney, An Adaptive QoS Routing Protocol with Dispersity for Ad-Hoc Networks, Proc. 36th Ann. Hawaii Int'l Conf. System Sciences, 302a, Jan. 2003.

Zhiqiang Shi, Ionescu, D., Dongli Zhang, A Token Based Method for Congestion and Packet Loss Control, Latin America Transactions, IEEE (Revista IEEE America Latina) 11(2), 2013.