

Cross layer design for rate selection and link failure prediction in MANETS

Aditi Marathe¹, Madhumita Chatterjee² and Satish Devane³

¹Ramrao Adik Institute Of Technology, University of Mumbai
Maharashtra, India

Abstract. Recently, in an effort to improve the performance of wireless networks, there has been increased interest in protocols that rely on interactions between different layers. The nature of temporary links and the mobility of the nodes together with wireless transmission effect on attenuation, interference, and multipath propagation, raise some inherent issues of mobile ad hoc networks. Cross-layer design allows us to make better use of network resources by optimizing across the boundaries of traditional network layers. It is based on information exchange and joint optimization over two or more layers. In this paper we propose two schemes to achieve rate adaptation by sharing signal information between Physical and Mac layers, and to deal with frequent route failures in Manets by identifying soon to be broken links. The cross layer processing for both the schemes proposed have been tested using Network Simulator NS-2.

Keywords: Cross layer design, DSR, MANETS

1. Introduction

TCP (Transmission Control Protocol) was designed to provide reliable end-to-end delivery of data over unreliable networks. In theory, TCP should be independent of the technology of the underlying infrastructure. In particular, TCP should not care whether the Internet Protocol (IP) is running over wired or wireless connections. In practice, it does matter because most TCP deployments have been carefully designed based on assumptions that are specific to wired networks. Ignoring the properties of wireless transmission can lead to TCP implementations with poor performance [5]. Thus, the cause of TCP performance degradation in MANETs are due to two major problems. The first problem is, TCP is unable to distinguish between losses due to route failures and network congestion. The second problem is, TCP suffers from frequent route failures. One way in which these limitations can be addressed is to introduce cross layer design features. Cross layer design involves the passing of information between layers, so that the functions carried out at a specific layer can take account of dynamic variations at other layers and adapt accordingly instead of making decisions based on predefined criteria.

We propose a cross layer interaction system that consists of two schemes, one in which we have MAC level rate selection based on signal strength information from physical layer and second wherein route failure problem of MANETS is handled by considering the link failure in advance based on channel condition. Section 2 gives a brief review of lists of contribution in the area of cross layer design. Section 3 describes our proposed work. Simulation results are presented in section 4. Section 5 presents conclusion and future work.

2. Literature Survey

The layering design of the standard protocol stacks has achieved great success in wired networks. It separates abstraction from implementation and is thus consistent with sound software engineering principles information hiding and end-to-end principle. However, protocol stack implementations based on layering do not function efficiently in mobile wireless environments. This results from the highly variable nature of wireless links and the resource limitation nature of mobile nodes. As a solution, there has recently been a proliferation in the use of cross layer design techniques in wireless networks.

A brief survey on the challenges TCP has encountered i.e., the channel error, the medium contention and collision, the mobility, the multi-path routing, and congestion is elaborated [5] and its impact on TCP is discussed. Some of the solutions to overcome it are TCP with feedback, TCP without feedback and TCP with lower layer enhancement. Through the use of feedback information to signal non-congestion-related causes of packet losses, the feedback approaches help TCP distinguish between true network congestion and other problems such as channel errors, link contention, and route failures. On the other end of the solution spectrum, TCP without- feedback approaches makes TCP adapt to route changes without relying on feedback from the network, considering that feedback mechanisms may bring about additional complexity and cost in ad hoc networks. The third class of approaches, i.e. TCP with lower layer enhancement, starts with the idea that TCP sender should be shielded from any problems specific in ad hoc networks while lower layers such as routing layer and MAC layer need to be tailored with TCP's congestion control algorithms in mind. This guarantees that TCP end-to-end semantics is maintained for ad hoc networks to seamlessly interconnect with the wired Internet. A snapshot of various cross layer design proposals is shown in the following figure 1 [4].

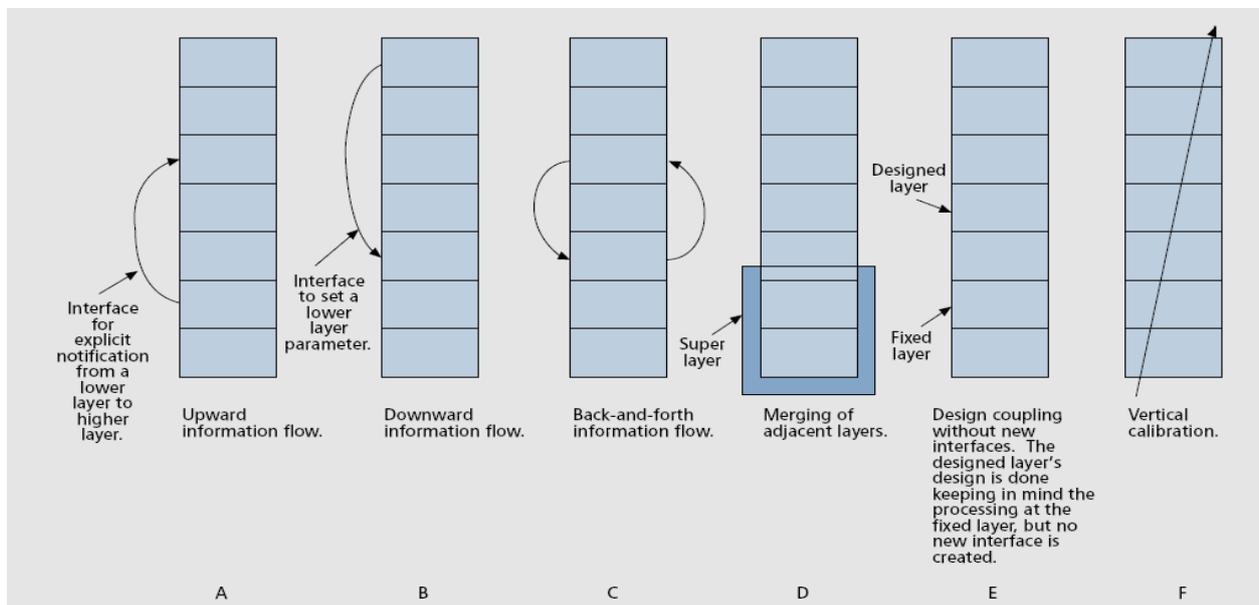


Fig. 1: Various proposals for cross layer design

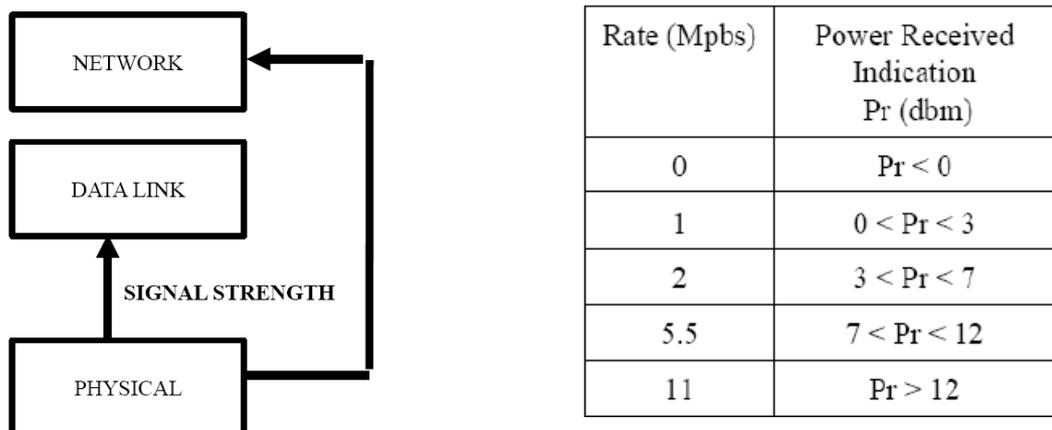
The layered architecture can be violated as creation of new interfaces(Figs. 1a–c), merging of adjacent layers (Fig. 1d), design coupling without new interfaces (Fig. 1e) and vertical calibration across layers (Fig. 1f) The various cross-layer feedback possibilities and their potential benefits are presented in [8]. The basic functions of each layer of TCP/IP, the information each layer contains and how each layer can interact with upper and lower layers are discussed in detail. Based on applications' dynamic resource requests the need for application-aware adaptive communication in mobile ad hoc networks that creates network routes is addressed in [3]. Cross-layer Discovery and Routing (CDR) is presented that alleviates the need for applications in a mobile ad hoc network to contact a well-known repository to create routes among mobile hosts. By exerting cross-layer design, how Cluster Based Routing Protocol (Cross-CBRP) can be optimized is discussed in [2]. Rate of cluster head changes, throughput and packet delivery ratio are evaluated using NS2. Comparisons denote that Cross- CBRP has better performances with respect to the original CBRP. Y.-C. Hu and D. B. Johnson [7] demonstrated the performance improvement resulting from the use of congestion information from MAC layer in network and transport layer. In network layer, the congestion information can be used to allow the routing protocols avoid selecting route through the congestion area. Within transport layer, the congestion level measurement may be applicable for several modifications of TCP, based on setting the Explicit Congestion Notification (ECN) [15] bits in a packet's IP header or using Wireless ECN (W-ECN) [4] or Explicit Transport Error Notification (ETEN)[12]. However, various cross layer designs can lead to negative consequences with undesirable effect on overall system performance. V.

Kawadia and P. R. Kumar [6] presented that the unbridled cross-layer design can lead to spaghetti design, which can stifle further innovation and be difficult to upkeep.

3. Proposed Schemes

We describe our proposed cross-layer system that consists of two schemes (i) transmission rate selection selects data rate in the MAC layer based on the channel estimation information from physical layer [1] (ii) prediction of soon to be broken link to reduce the likelihood of data packets being dropped by using received signal power measurement from physical layer in network layer to perform a route rebuild prior to the link breakage.

Scheme I: Rate adaptation is the process of dynamically changing data transmission rate based on the channel quality estimation. If the channel is changing faster than it can be estimated and fed back to the transmitter, adaptive techniques will perform poorly. R. Krishnan and Allman [12] observed that channel quality information is more efficiently and timely acquired at the receiver than at the sender. In this scheme, a source node sends a RTS packet before it transmits any data. When the destination node receives this RTS, it estimates the signal strength of the transmission channel. Then the signal strength is mapped to a transmission data rate based on simple threshold based technique. The rate to be used to send the data frame is then returned to the sender in the CTS frame. The RTS, CTS and data frames are modified to include information on the rate of the data frame transmission to allow all the nodes within the transmission range to correctly update their NAV. In this scheme, the rate is chosen by comparing the channel quality estimation against a series of thresholds related to the available M-QAM modulation schemes [14]. Power Received Indication is the difference between the received power strength and the threshold. The thresholds we used in the simulation are as shown in the table.



Scheme II: In this scheme, an optimistic radio transmission model is used. According to the NS2 implementation, Two Ray Ground Reflection Approximation is used as radio propagation model [16]. At near distances, Friss free-space attenuation ($1/r^2$) is used, at far distance, an approximation to Two Ray Ground ($1/r^4$). Because we are concerned with mobile nodes that are going to move out of the senders' transmission range, the scheme is based on Two Ray Ground Reflection model. According to the NS2 implementation, the Two Ray Ground Reflection equation is:

$P = P_t * G_t * G_r (h_t^2 * h_r^2) / d^4$ where: P and P_t is the signal power at receiver and transmitter respectively, G_t and G_r is the gain for a signal to a node from the transmitter and from receiver respectively, h_t and h_r is height of transmitter and receiver antenna and d is the distance between transmitter and receiver.

We can assume P_t as a constant. Also, in our wireless ad hoc network simulation, a directional antenna is used. Further, we assume the ground is flat, and that h_r and h_t are constants. So we can simplify equation under the conditions of ad hoc wireless network simulation: $P = k * P_t / d^4$ where $k = G_t * G_r * (h_t^2 * h_r^2)$ is a constant. This equation means the signal power at receiver node has relation ($1/d^4$) with the distance between the sender node and receiver node. The purpose of scheme II is to reduce the dropped packets by predicting the link failure. In the implementation, for each mobile node, information of decreasing signal power

strength for three packets along with the reception time is maintained for neighboring mobile nodes. This information is then used at the network layer by DSR routing protocol [9] to decide whether the link is going to break in the future or not based on the reception time of the packet that is stored and the time when the route is selected. If prediction is made that the route is going to fail in near future, then alternate path is chosen to avoid packets being dropped on broken link. The various information stored from physical layer is as shown below.

Current hop node address	Previous hop node address	Signal power	Packet count	Reception time
--------------------------	---------------------------	--------------	--------------	----------------

Atleast three packets are needed to correctly guess whether a link is going to fail or not so as to avoid false predictions. Sample information stored for the network with ten nodes is as shown in the following table II.

4. Simulation Results

The simulations were performed using ns-2 with its wireless extensions developed by the Monarch Project [16]. The application traffic pattern consists of CBR nodes running on UDP within 1000 m×1000 m area. The traffic of CBR connection begins at randomly generated start time within 1 second from the beginning of the simulation and the simulation stops after 800 seconds. By using scheme I, throughput (fig 3 & 4) is improved and end to end delay (fig 5 & 6) is significantly reduced as compared to single rate transmission.

Link	Signal Power	Packet count	Reception Time
0 - 6	-69.252563	0	0.254067
	-70.394552	1	0.377364
	-3022.963608	2	7.922938
2 - 5	-61.246082	0	0.265557
	-69.932727	1	83.703871
	-73.485466	2	83.806807
4 - 1	-55.155474	0	0.273340
	-62.260273	1	0.309335
	-70.394552	2	0.313817
7 - 2	-55.840669	0	0.266566
	-68.866365	1	49.371984
	-71.528734	2	50.988933
2 - 4	-41.140098	0	0.265556
	-43.759678	1	49.377342
	-63.743496	2	83.701864

Table II

Throughput graph

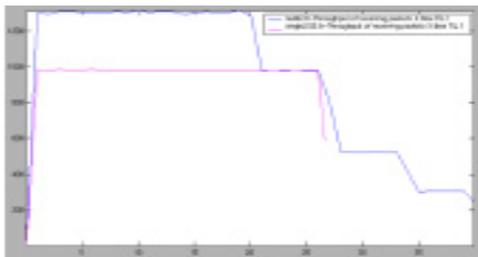


Fig. 3: for two nodes using scheme I (blue) and single rate transmission (pink)

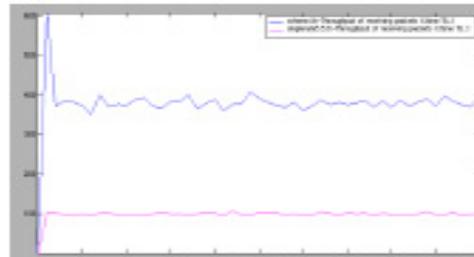


Fig. 4: For 10 nodes using scheme I (blue) and single rate transmission (pink)

End to end delay

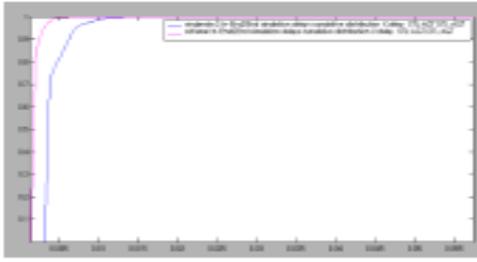


Fig. 5: For two nodes using scheme I (blue) and single rate transmission (pink)

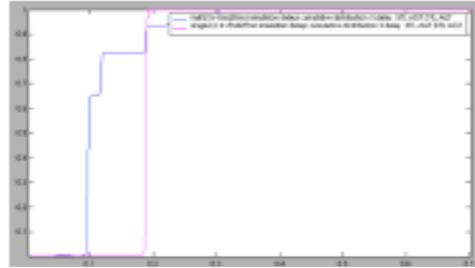


Fig. 6: For 10 nodes using scheme I (blue) and single rate transmission (pink)

Total packets dropped

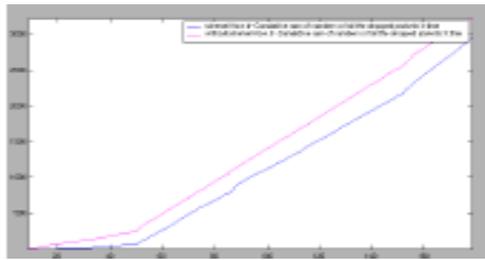


Fig. 7: Graph for total packets dropped for max speed 1 m/s with (blue) and without scheme II (pink)

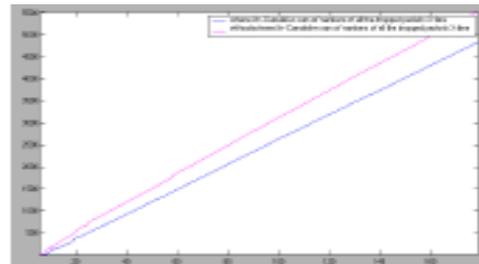


Fig. 8: Graph for total packets dropped for max speed 20 m/s with scheme II (blue) and without scheme II (pink)

5. Conclusion and Future Work

In this paper, we briefly discuss performance optimization design challenges of ad hoc networks and how network performance can be improved by using cross-layer design. Simulation results show that cross-layer design yield significantly improved performance by exploiting the tight coupling between the layers in wireless systems. Significant performance improvement can be achieved by MAC level rate adaptation based on signal strength information from physical layer. However, in scheme I, use of RTS-CTS packets is mandatory. Future work involves how scheme I can be changed that will work without RTSCTS. In most mobile ad hoc network routing protocols, sources will use a route until a link is broken or a shorter route is found. A link failure will cause packets to be dropped resulting in significant throughput degradation. Link status is predicted and added in DSR protocol in scheme II which resulted in significant reduction in total packets dropped due to link failure. Future work involves how prediction ability of scheme II can be improved. Also, more experiments can be done on the effect of different number of mobile nodes and simulation area.

6. References

- [1] Ning Yang, Ravi Sankar and Jungsik Lee, "Improving Ad hoc network performance using CLD", IEEE 2009
- [2] Sayed Kazen Jahanbakhsh Marzieh Hajhosseini, "Improving Performance of Cluster Based Routing Protocol using Cross-Layer Design", Advances in Computer Science and Engineering 13th International CSI Computer Conference, March 2008
- [3] Christine Julien and Meenakshi Venkataraman "Cross-Layer Discovery and Routing in Reconfigurable Wireless Networks", 2006 IEEE International Conference on Volume, Issue, Oct. 2006 Page(s):119 – 128
- [4] Vineet Srivastava, Mehul Motani "Cross Layer Design: A survey and a road ahead", Communications Magazine, Volume 43, Issue 12, Dec. 2005 Pages: 112-119
- [5] Xiang Chen, Hongqiang Zhai, Jianfeng Wang, and Yuguang Fang "TCP Performance over Mobile Ad Hoc Networks", Electrical and Computer Engineering, Canadian Journal of Volume 29, Issue 1, Jan.-April 2004 Page(s):129 – 134
- [6] V. Kawadia and P. R. Kumar. "A Cautionary Perspective on Cross Layer Design". IEEE Wireless

Communications, 12(1):3–11, February 2005

- [7] Y.-C. Hu and D. B. Johnson, “Exploiting Congestion Information in Network and Higher Layer Protocols in Multihop Wireless Ad Hoc Networks,” In the 24th International conference on Distributed computing Systems (ICDCS 2004), pp.301-310, IEEE, Japan, March 2004.
- [8] V. T. Raisinghani and S. Iyer. “Cross-layer Design Optimizations in Wireless Protocol Stacks”, Computer Communications (Elsevier), 27(8):720–724, May 2004.
- [9] B. David Johnson, A. David Maltz, and Y. Chun Hu, "The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)," IETF INTERNET DRAFT, 24 February 2003
- [10] S. Shakkottai, T. S. Rappaport and P. C. Karlsson, “Cross-layer Design for Wireless Networks,” IEEE Communications Magazine, pp.74-80, October 2003.
- [11] W. H. Yuen, H.-no Lee and T. D. Andersen, “A Simple and Effective Cross Layer Networking System for MobileAd Hoc Networks,” IEEE PIMRC, Vol.4, pp.1952–1956, September 2002.
- [12] R. Krishnan, M. Allman, C. Partridge, and J. P.G. Sterbenz, “Explicit Transport Error Notification (ETEN) for Error-Prone Wireless and Satellite Networks,” BBN Technical Report No. 8333, BBN Technologies, March 2002.
- [13] F. Peng and J. Ma, “An Effective way for Enhancement of TCP Performance in Wireless and Mobile Networks,” Internet Draft, draft-fpeng-wecn-04.txt, June 2001.
- [14] A. J. Goldsmith and S. -G. Chua, “Variable-rate variable power M-QAM for fading channels”, IEEE Trans. On Communications, Vol. 45, pp. 1218-1230, Oct. 1997.
- [15] S. Floyd, “TCP and Explicit Congestion Notification,” ACM Computer Communication Review, Vol.24, No.5, pp.10-23, October 1994.
- [16] Marc. Greis, Ns. The Network Simulator Tutorial