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An Enhanced Accessible Bandwidth Assessment Procedure for an End-To-End Network Path

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ABSTRACT: This paper presents a unique probing scheme, a rate adjustment algorithm, and a modified excursion detection algorithm (EDA) for estimating the available bandwidth (ABW) of an end-to-end network path more accurately and less intrusively. The proposed algorithm is based on the well-known concept of self-induced congestion and it features a unique probing train structure in which there is a region where packets are sampled more frequently than in other regions. This high-density region enables our algorithm to find the turning point more accurately. When the dynamic ABW is outside of this region, we readjust the lower rate and upper rate of the packet stream to fit the dynamic ABW into that region. We appropriately adjust the range between the lower rate and the upper rate using spread factors, which enables us to keep the number of packets low, and we are thus able to measure the ABW less intrusively. Finally, to detect the ABW from the one-way queuing delay, we present a modified EDA from Path Chirps' original EDA to better deal with sudden increase and decrease in queuing delays due to cross traffic burstiness. For the experiments, an Android OS based device was used to measure the ABW over a commercial 4G/LTE mobile network of a Japanese mobile operator, as well, as real testbed measurements were conducted over fixed and WLAN network. Simulations and experimental results show that our algorithm can achieve ABW estimations in real time and outperforms other start-of-the-art measurement algorithms in terms of accuracy, intrusiveness, and convergence time.

KEYWORDS: MANETs, Proactive Routing, Reactive Routing, Hybrid Routing, Network Topology, Routing Metrics, Quality of Service.

I. INTRODUCTION

Available bandwidth (ABW) estimation is crucial for traffic engineering, quality-of-service (QoS) management, multimedia streaming, server selection in application services, congestion management, and network capacity provisioning in wireless mobile networks. ABW measurement can be considered essential to ensure that wireless mobile operators can achieve the QoS standard guaranteed by them while providing desired data rates to users. This can also be considered when comparing the performance index of various Telecom operators in a specific region. Mobile Ad-hoc Networks (MANETs) comprises of independent mobile nodes that are randomly deployed and can leave or join the network on the move. These nodes communicate with each other via wireless links to exchange information. Ad hoc allows new devices to be added quickly. Each device in the network can freely move in any direction that results in dynamic topology. Designing a network is very difficult task as there are lots of challenges and issues in its design. Each node can act as router which forwards packet from source to destination. These nodes can be any personal device such as laptops, mobile phones etc. MANETs and IOT applications span from small networks to very large dynamic networks. Examples include military applications, low level like class room conference room, automated battle field, rescue operations, emergency operations and also being used in VANET (Vehicular Ad hoc network). In these networks, nodes communicate with each other in multi hop fashion. When sender transmits data packet to destination node, it uses some intermediate node for communication. So each node in the networks plays equally important role. To meet the demands of design constraints of IOT enabled MANETs, an efficient routing scheme is required.



II. METHODOLOGY

2.1 PACKET GENERATION ALGORITHM

Our proposed idea, NEXT, estimates the ABW along a network path by launching a number of packet chirps (numbered $c = 1, 2, 3 \dots$) from sender to receiver. Each chirp consists of a certain number of packets that depend on the lower rate, the upper rate, and the spread factor. Assume that chirp C consists of N packets. The ratio of successive packet inter-spacing times within a chirp is defined as the spread factor. In NEXT, we have two spread factors: γ_1 and γ_2 . First, we divided the total range of rates into three regions in terms of the number of packets. NEXT used N number of packets to test the values between the lower rate L and the upper rate H . We have divided the entire range of rates from L to H into three portions, where P_1 and P_2 are two region intersecting points. We set the initial rate as $R_0 = L$. Successive rates will be generated according to whether the current rate falls within the P_1 to P_2 region or not. If the current rate R_i falls within P_1 to P_2 , then the next rate is calculated as $R_i = R_{i-1} \times \gamma_2$. Otherwise, the rate will be $R_i = R_{i-1} \times \gamma_1$. We used spread factor $\gamma_2 = 1.1$ from the P_1 to P_2 region of the total range of rates. In other areas, we used the spread factor $\gamma_1 = 1.2$ (adapted from Path Chirp's experimental evaluation). NEXT is based on the observation that the smaller the sample intervals around the turning point, the more accurately we can find the ABW at that turning point. Here chirp Rate is the number of bits sent per second. Packet sizes are considered in computing the chirp rate. Since we have three different regions in a single packet train, we calculate the time duration of three separate portions and then add them together to obtain the total chirp duration.

2.2 RATE ADJUSTMENT ALGORITHM

Rate adjustments of L and H are performed if the feedback value from the NEXT receiver to the NEXT sender is close to L or H , and whenever the feedback value does not fit into the P_1 to P_2 region. Details of the algorithms pseudo-code can be found. For the case of understanding, we will describe our rate adjustment algorithm pictorially in this paper. Describes our rate adjustment algorithm. The horizontal line represents the rate of packets where L is the lower rate and H is the higher rate. The individual red dots represent the packets with different rates. For comprehensive understanding, the spacing's between the red dots are set equal here but this does not mean that the rate intervals among these red dots (packets) are equal. The consecutive actions for any particular conditions are going from top to bottom and are indicated by line 1, 2, 6, where line 2 and line 3 are derived from line 1, and line 5 is derived from line 4, and line 6 is derived from line 5. The rate adjustment algorithm stops adjusting rates when the condition of $P_1 < ABW_{inst} < P_2$ is satisfied, where ABW_{inst} is the instantaneous ABW feedback by the receiver to the sender in a single round of measurement.

2.3 MODIFIED EXCURSION DETECTION ALGORITHM

From Path Chirp's original Excursion Detection Algorithm (EDA), we have developed a modified EDA. Path Chirp estimates the ABW by launching a series of particular packet trains, called chirps, each of which consists of k packets sent with an inter-packet gap that is exponentially reduced. The chirps (numbered $m = 1, 2, 3 \dots$) are sent from sender to receiver and then statistical analysis is conducted at the receiver by taking into account the one-way-delays (OWD), $q(m)_k$, faced by each packet k on the intermediate router. A typical OWD signature Path Chirp uses the shape of the signature to make an estimate $E(m)_k$ of the per-packet available bandwidth $B[t(m)_k, t(m)_{k+1}]$, where $t(m)_k$ is the sender transmission time of packet k . It then takes a weighted average of the $E(m)_k$ corresponding to each chirp m to obtain estimates $D(m)$ of the per-chirp ABW.

2.4 PACKET LOSS RECOVERY (PLR) ALGORITHM

Packet loss in a wireless network is an inevitable issue that impacts the accuracy of ABW estimation. Some tools, e.g., Path Chirp and Path load, discard estimates when packet loss occurs to avoid errors in ABW estimation computation. However, this results in longer and more variable measurement times. So, instead of discarding estimates when packet loss occurs, we reconstruct the one-way queuing delay curve by considering whether a single packet loss occurs or multiple packet losses occur. We recover the possible queuing delay information of the lost packet (Ld) based on the previous packet's queuing delay (Pd) and the next packet's queuing delay (Nd) information in case of single packet loss, and in case of multiple packet losses, we used packet loss rate information.

2.5 RATE CONTROL ORIENTED PROTOCOLS

In this type of protocols, congestion is avoided based on the transmission rate. For this purpose, network status is shared with sending node so that if there is any congestion on intermediate node or if there any bottleneck link is created somewhere in middle then sending node reduces its sending rate so that congestion is avoided. Many



techniques have been proposed in literature for rate control mechanism, some of them are listed below; Soundararajan and Bhuvaneshwaran, has proposed a mechanism called multipath load balanced and rate based congestion control (MLBRCC). In this technique, the destination node transmits network information to the application which then adjusts its sending rate according to network conditions. There are so many other techniques in literature in which sender adjusts its data rate according to network condition. These schemes include linear message rate integrated control avoids congestion by taking benefit of precision control which are by default available in wireless. Rate effective network utility maximization (RENUM) works by decreasing data rate of link from source to destination.

III. BANDWIDTH AWARE ROUTING STRATEGY

In this section, we have presented an efficient Bandwidth Aware Routing Strategy (BARS) for identifying path between sender and receiver. We have analyzed the available bandwidth and residual queue size to decide about recommending a suitable bandwidth value for data exchange. We have worked for following new features in the AODV, 1.) Ability to estimate the residual bandwidth. All nodes along the path are capable to know their available resources in terms of bandwidth. 2.) Informs source node about current network conditions in terms of residual bandwidth so that source node can adjust its transmission rate accordingly. 3.) The route recovery process immediately performs route recovery whenever there is a broken route in network. To accommodate the above mentioned features, the packet format is changed. For example, to implement quality of service, some new fields are added into packet format. These fields are added to RREQ and RREP packets in order to carry out the bandwidth information. The major difference between the proposed methodology and other mechanisms based on AODV is the implementation of adaptive feedback method.

IV. PHASE I -RESIDUAL BANDWIDTH CALCULATION

During first phase, residual bandwidth is calculated on each node which is based on two steps, In first step, any node in the network N_i locally calculates residual bandwidth by sending residual bandwidth request to each neighbor node N_j and saves the value of transmission time and cost of transmission messages. Where as in the second step weight age average of previous residual bandwidth is calculated in order to inform the source node regarding the latest residual bandwidth available in network at each link. Using this information source node can adjust its sending data rate in order to avoid congestion.

V. TRANSMISSION OF RREQ PACKET FROM SOURCE IN BARS

In BARS, route is selected based on source requirement. Source indicates the minimum requested bandwidth that must be guaranteed, in RREQ packet. This packet with requested bandwidth titled as Bandwidth-oriented Route Request (BRREQ). The new packet with bandwidth extension includes session id (*sid*) with source address. Session id uniquely identifies each flow and is incremented by timer each time when new RREQ is generated. When a node receives a BRREQ packet, reverse route is created with *sid* and BRREQ is rebroadcasted. The same procedure continuous until BRREQ reaches at destination.

VI. RECEIVE AND LOOKUP FOR BANDWIDTH REQUEST AT INTERMEDIATE NODE

Each node which receives BRREQ packet, it first extracts headers from the received packet. When BRREQ packet is received by an intermediate node, it checks either it has route to destination or not. If receiving node has route to destination, it then compares the values of requested bandwidth with residual bandwidth of each node. If requested bandwidth is less than node residual bandwidth, intermediate node forwards data packet. This can be done by sending immediate cache update message to the last node. This message includes bandwidth value of next link which is greater than previous link. If there are two paths to destination with same distance and one of the outgoing links is being used by multiple senders, then there are chances of packet drop on that link. In this situation, node transmits packet on link with higher bandwidth to avoid congestion. The throughput in static scenario where data rate is varied from 2000 to 1000 bits per second. Results show that by increase in data rate throughput also increases. Throughput is also inversely proportional to congestion in network. In proposed scheme, we have handled congestion successfully that's why throughput of our proposed scheme is much greater than DRA. Results depict that throughput Receive and Lookup for Bandwidth Request at Intermediate Node.

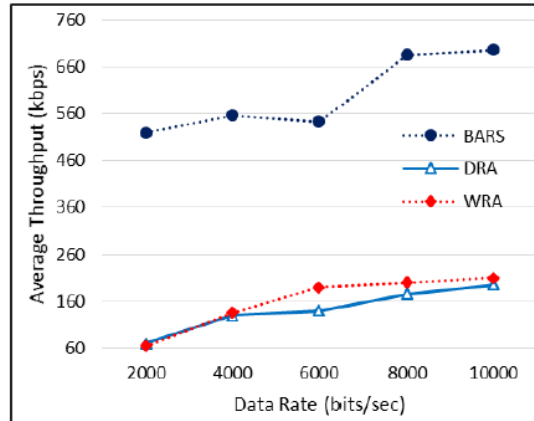


Figure 6.1: Receive And Lookup for Bandwidth Request At Intermediate Node

VII. CONCLUSION

In this work, we presented the details of NEXT-V2, an extended version of NEXT, an active probing algorithm that features an efficient measurement scheme for end-to-end ABW estimation in a fixed, WLAN and 4G/LTE network. We have proposed a unique packet train structure, an optimal rate adjustment algorithm, and a modified excursion detection algorithm to identify the ABW with higher accuracy, less convergence time, and less overhead. NEXT-V2 is compared with other existing ABW estimation tools in a simulation and real test bed to prove its algorithmic strength. From the real test bed results, we can see that 90% of the cases NEXT-V2 reports a less than 10% error. On the other hand, NEXT and PathChirp reports a less than 10% error for 70% and 20% of the cases respectively. Intrusiveness of NEXT-V2 is reduced by 50% as compared to that of PathvChirp. From experiments on a 4G/LTE network, a few conclusions can be drawn. First, current bandwidth estimation tools are significantly impacted by wireless network conditions, such as contention from other traffic and rate adaptation. This yields inaccurate estimates, high and varying convergence times, and intrusiveness. Thus, current tools are generally impractical for applications such as streaming multimedia that require fast, accurate, and non-intrusive bandwidth estimations even when the last hop is over a WLAN. Second, the experiments conducted and results achieved on a commercial 4G/LTE network show the ability of NEXT-V2 to make quick and less intrusive ABW estimations, with higher accuracy. A less than 15% error is reported in case of down-link ABW estimation for 80% of the cases and a less than 20% error is reported in case of up-link ABW measurement for 70% of the cases. Comparison of ABW estimations with FTP throughput measurements on Android OS is carried out using various real-time cross traffic. This measurement tool uses minimal power and network resources making it possible to conduct multiple test sessions. It provides rich data sets with ABW estimations with associated geo-location values. The ideal tool would be one that provides accurate estimations, less overhead, quick response time, and 100% reliability, whereas there is no mandatory requirement for the ideal tool in all scenarios. Tool selection is based on the application and the network environment.

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