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Fast Path Reservation Scheduler

Vidya Sachin Kubde, Datta Meghe College of Engineering, India*
Sudhir D. Sawarkar, Datta Meghe College of Engineering, India

ABSTRACT

In multihomed devices, multipath transmission control protocol is a transport layer protocol that allows TCP segments to be sent over several paths. The authors look at several multipath TCP schedulers in this study and highlight some current outstanding concerns including head-of-line blocking, bandwidth aggregation, and out-of-order packets. The majority of these difficulties degrade MPTCP performance, which may be improved by constructing an MPTCP scheduler properly. Then, utilizing the bandwidth of all potential routes, they develop a novel MPTCP packet scheduler dubbed a fast path reservation scheduler that not only helps to solve the aforesaid problems, but also delivers optimal throughput with a short execution time. The size of the receiver buffer or the size of the data being transmitted have no effect on the performance of FPRS, which transmits packets of data to the receiver in the order they were received. Both empirically and analytically, the authors show that the suggested scheduler outperforms the competition.

KEYWORDS

Head of Line Blocking, MPTCP Scheduler, Path Utilization

INTRODUCTION

MPTCP is a TCP extension designed for today's multihomed devices. The IETF's Multipath TCP working group Baidya and Prakash (2020) is working on MPTCP. TCP is a commonly used single path protocol that must be re-established if it fails. To deal with network failures, MPTCP estab- lishes a single connection with all accessible interfaces Baidya and Prakash (2020).It supports different TCP connections for a single stream of data in an efficient way[fig1].MPTCP is also advantageous for resource utilization and bandwidth aggregation Paasch and Barre (2014).The Linux Kernel MPTCP implementation Apple (2017) is one of the most frequently used MPTCP implementations today, aside from Apple's implementation for Siri Postel (1981).

MPTCP relies on two main components: congestion management and packet scheduling . The congestion control limits the number for every path's congestion window and updates this after every packet transmission Chaturvedi and Chand (2018). A scheduler assigns the packets to the available paths. A wrong scheduling decision leads to decrease in performance of MPTCP in both the heterogeneous networks and homogeneous networks such as decrease in throughput, higher download time, poor path utilization Barre´et al. (2011). Path heterogeneity causes an increase in out-of-order packets, which causes a Head of Line (HOL) blocking issue due to receiver window limitations. An

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optimized packet scheduler will use all available paths and reduce out-of-order packets to increase throughput and download time Scharf and Kiesel (2006).

We propose the Fast Path Reservation Protocol (FPRS) to tackle HoL blockage, out-of-order delivery, and bandwidth aggregation. This leads in faster completion times and in-order delivery . The FRPS is tested in the Linux kernel Paasch and Barre (2013) . We compare FPRS ' performance to various current packet schedulers in terms of throughput, completion time and Bandwidth agregation .

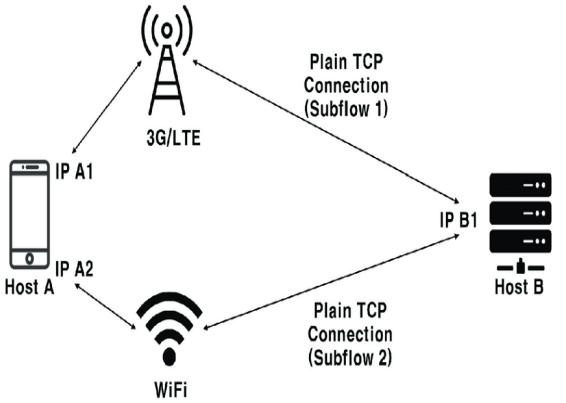
On the rest of the paper: Section 2 explains packet schedulers' history. This section examines existing scheduler vulnerabilities. inspiration for a new packet scheduler Sect. 3 shows the research work (FPRS). In Section 4, we compare the FPRS scheduler's performance to other Linux schedulers.

BACKGROUND & MOTIVATION

In single path TCP, packets arrive in sequence assuming they are neither lost nor re transmitted Hurtig (2018). Packets are out of order at the recipient end due to MPTCP's numerous routes Paasch (2013). Head of Line Blocking (HOL) reduces throughput.

RFC Ford et al. (2020) defines MPTCP. Recent research has focused on MPTCP

Figure 1. 1 Bandwidth Aggregation in Multipath TCP



Implementation, design, and performance Kimura et al. (2020) . The scheduler picks paths to maximise performance over single path TCP. . The scheduler is invoked when the application layer delivers a new packet or an acknowledgement Bonaventure et al. (2017) . The scheduler will obtain the route characteristics, RTT, signal strength, throughput, and loss rate. These characteristics are used to analyse the transmission performance of the routes. To create the connection, the optimum path is picked.

The unsolved difficulties of packet scheduling in MPTCP have been extensively researched. Some works employ Round Robin Hwang and Yoo (2015). This scheduler selects routes consecutively. It couldn't work in diverse networks. The solution was MinRTT, which picks the path with the least RTT. MinRTT is now the default MPTCP scheduler Raiciu (2012). The congestion window determines the data flow on this route. Surprisingly good except for memory-constrained de- vices with a tiny receiving window Raiciu (2012) discovered this to eliminate head-of-line blockage caused by a small receiver window. Similarly, DAPS Kuhn et al. (2014) used the forward delay, which is the transmitting time plus the in-flight time, to estimate packet delivery time. While the work increased accuracy, the delay aware scheduler is only helpful while RTT and congestion window stay constant. As a result, DAPS cannot handle network disruptions.

Yang Yang et al. (2014) offers an OTIAS method to address this issue utilizing current data. Its work is dependent on scheduling more segments on a sub-flow than it can send. Lim thinks the fast way is underutilized in ECF Lim (2018) . This reduces the time a rapid sub-flow is idle. The principle is the same as Blest Ferlin (2016), except it encourages only fast pathways. CP Lim (2018) aids by slowing down. It prefers to pre- vent sluggish paths that cause performance concerns. Unavailable routes are occasionally preferred in the default scheduler, according to STTF Hurtig (2018). STTF works by calculating each segment's transmits time while taking into account data currently in flight. It deals with out-of-order packet transmission and receiving.

Alternative Multipath Scheduling Options TCP Shi et al. (2018) suggested methods for selecting routes for diverse purposes; one strategy deals with flow sending rate, while the other utilizes the great- est available congestion window space. In Qaware, Shreedhar was inspired by the issue that the most commonly utilized sub-flow steadily in- creases its end-to-end latency, making it less desirable to use. Using end-to-end delay (local device driver queue occupancy plus end-to- end delay measurements), they identified a path. Remp Frogmen (2016) is a scheduler that uses all pathways but transfers the same data on both. Not only does it reduce latency, but it also improves throughput.

DEMS Guo and Ethan (2017) argues that careful scheduling can minimize download time. It does so by decoupling the two routes, transmitting data forward on one and backward on the other. It also conducts data re-injection to speed up downloads. Table I summarize the schedulers, emphasizing their techniques and approaches.

MPTCP performance degrades as a result of receive window restrictions, HoL blocking, and packet ordering issues. The large receiver buffer size helps to maximize the bandwidth available on a route. In a normal TCP connection, the size of the buffer is determined by the amount of bytes or packets that are still outstanding.

Returned bytes or packets define the buffer size in a normal TCP connection . B_k is bandwidth and rttk = route k round-trip time.

$$B\mathbb{k} = RTT\mathbb{k} * C\mathbb{k} \tag{1}$$

As demonstrated in Eq 1, the needed buffer size for multi-path TCP is significantly bigger. Mobile and other tiny multi-homed devices have a memory buffer that cannot handle the full bandwidth of all accessible routes. MPTCP delivers out-of-order packets due to numerous routes. The small receiver buffer size starts dropping packets out of order, causing receive window restriction and HoL blocking difficulties, reducing throughput. If we fix the receiver buffer's out-of-order packet problem, the buffer size has no influence on MPTCP performance. A packet scheduler can tackle the problem of out-of- ordering. Our new packet scheduler enhances throughput while reducing completion time and assuring in-order delivery.

PROPOSED WORK

As previously stated, a packet scheduler is important to MPTCP network productivity. In-order data packet delivery, receive window constraints, lengthy completion times, and HoL blocking are difficul- ties with existing packet schedulers. A new MPTCP packet scheduler is proposed named as Fast path reservation protocol (FPRS).

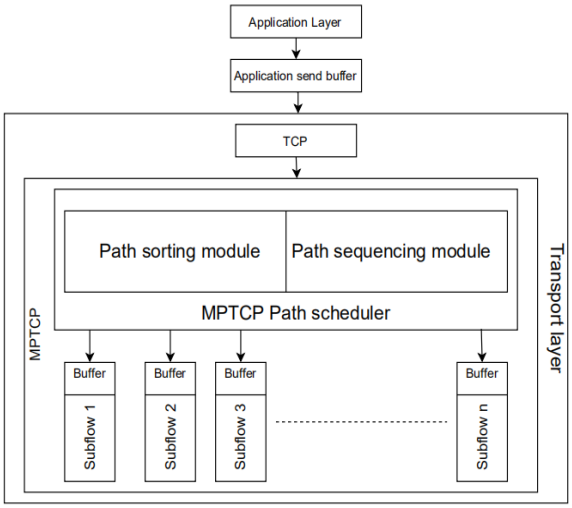
(1) The receiver buffer should receive packets in succession. (2) all routes' bandwidth should be used (3) completion time should be as short as feasible When the first requirement is met, the FPRS is capable of overcoming Head of line blocking and receive window constraints. In this way, it lowers packet loss and increases speed. The second condition aggregates each interface's bandwidth by using Handley et al. (2020) all accessible routes to the MPTCP source. The third criteria help choose each packet's path so that the total network completion time is maintained low. Because these

three aims work together, FPRS outperforms previous schedulers in terms of performance, as shown experimentally and analytically in the next section.

System Model

The MPTCP protocol is an extension of TCP that offers advantages for bandwidth aggregation and performance for users, as well as content-rich real-time multi-stream media. These results, however, may be influenced by variables such as data scheduling methods and route characteristics, as well as the short, tight sorting restricted receiving buffer. Every bad scheduling choice is likely to have a significant impact on MPTCP throughput, which may lead to a deterioration in MPTCP performance. The suggested scheduler accommodates all network routes and provides a scheduling approach that in- cludes a data scheduling scheme that decreases re-transmission, reduces out-of-order packets, improves throughput, and ensures essential data transmission quality assurance.

Figure 2. System Architecture of Proposed Scheduler



The above graphic depicts the MPTCP data transmission system architecture, which comprises the MPTCP sender, the MPTCP receiver, and a multipath heterogeneous wireless network. Two modules, the Path Sorting Module (PSM) and the Sequencing Module, are included in the sender (SM). Data from the application layer is sent to the transport layer by a module in the sender. That module utilises PSM to sort the routes according to their arrival timings. The sequencing module will assign routes for data transfer in a certain order. The new multimedia multipathing data scheduler will send data packets based on the uniqueness of routes. By restructuring the data packets, the receiver will then transmit them to the top layer of the receiver, after which it will send back a SACK message to the sender.

Path Sorting Module

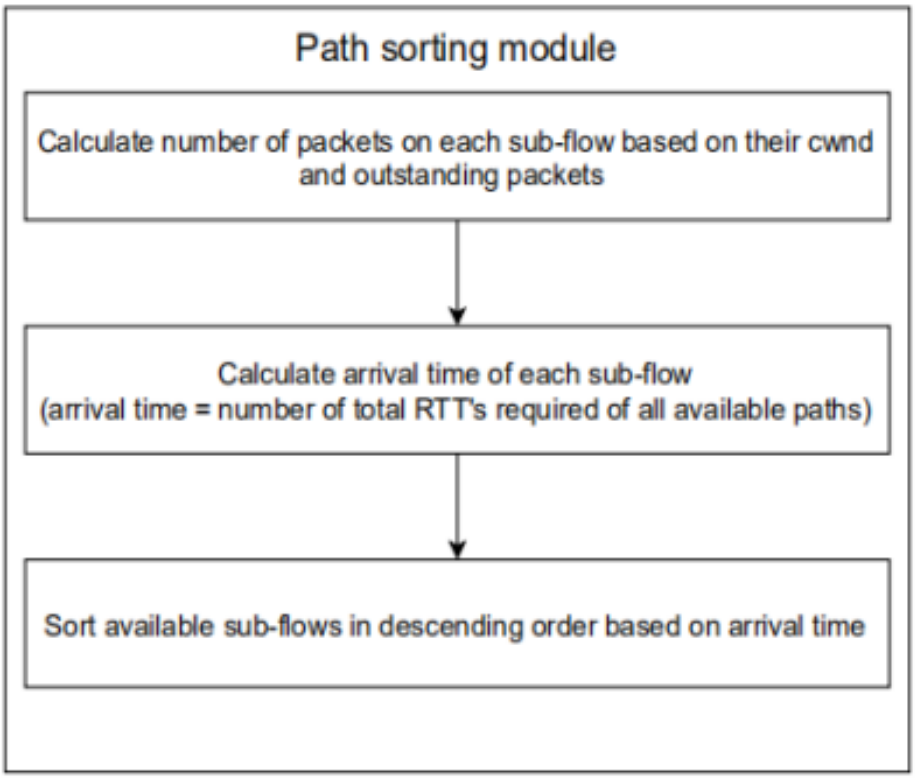
It is vital to note that all the existing schedulers (including the default) only schedule packets to subflows with available cwnds. To schedule data, only those subflows that have cwnd available are use- able. While the cwnd of the present subflows may be exhausted, nonetheless, under our recommended

scheduler, all existing subflows may be exploited to schedule data. To achieve this, we shall classify the routes depending on arrival time.

Now, how can the time of arrival be approximated for each subflow? A subflow's send buffer is made up of two things: data that is ready to be sent for the first time and data that is still pending (i.e., has previously been sent and awaiting acknowledgement) (i.e., has already been sent and awaits acknowledgement). These two sets of data are designated "Undelivered packets" and "Pending packets".

Arrival time of Path $_{\kappa}$= (Cwnd $_{\kappa}$-Pending Packets $_{\kappa}$)* Srtt $_{\kappa}$

Figure 3. Path Sorting Module



Sequencing Module

The suggested scheduling algorithm works first to minimise out-of-order packets and second to use all the routes. If a heterogeneous network uses all the available routes, it is certain to encounter slower packets and therefore will be unable to operate properly. All current schedulers thus attempt to avoid slow paths in order to minimise the number of out-of-order packets. This problem was addressed by the suggested scheduler, which found the gap between the available subflows and then placed packets on the sender side according to the gaps. This sequencing logic can make these scheduling requirements happen.

Sequencing Logic

The FPRS algorithm figures out the range of packet numbers that will be transmitted for each route such that the packets will be delivered in order and in the shortest amount of time to the receiver buffer. This path selection technique makes use of the fastest way from all accessible routes, then counts the packets in order by identifying them by their numbers.

1) Let the selected path is Pj with the lowest arrival time among the N available paths
2) Assume its congestion window is cwndj and round-trip time as RTTj.
3). Determine the number of packets that can be sent by these fast paths and the remaining N-1 paths during the interval from tslot + rttj. The path rj will appear rtti/rttj times for that interval, and each time it will send the packets equal to available space in its congestion window. In the same manner,proposed algorithm determines the number of packets that can be sent by all these N paths. Let the total number of predicted packets from all these N paths be K.
4). The path rj sends the number of packets equal to cwndj. After this transmission packets will be reserved on fast paths according to the ratio of RTTs with respect to slow paths.
5) Allot packets for remaining paths according to its RTT time slot availability.Send alloted packets on all N paths

This allows the FPRS to identify the packets' numbers along the route very accurately. This method is implemented in an algorithm, known as FPRS, which is used to schedule packets, as follows.

The description of the Proposed algorithm is defined as follows. The Proposed algorithm considers a set of all the available paths N from an MPTCP source as an input. It has some local variables that are initialized with some initial values as shown in lines 1–4. Every time the Proposed algorithm chooses a fast path P 1 that has minimum arrival time from all available window paths as shown in Path sorting Algorithm. Lines 12-18 finds sequence numbers for all the paths for first time slot. Lines 10-16 assign packets for fast path. Lines 19 to 32 finds packets for remaining paths while reserving packets for fast path. For next time slots Lines 32 to 34 finds sequence of packets for all the paths N . For each delivery, proposed algorithm find the number of packets with their sequence number for each such path by using the temporary variables as shown in lines Lines 23-31 .Each time when packets for remaining paths are calculated, the fast path is reserved first and later packets assigned for remaining available paths.

ILLUSTRATION OF WORKING FUNCTIONALITY OF SEQUENCING LOGIC

The proposed algorithm is presented below. The recommended approach takes as input a list of all possible MPTCP routes N. It contains numerous special variables that are first initialized with specific values, and all of the routes' arrival times are calculated. As shown in, the proposed method selects the shortest route P 1 with the least arrival time among all possible window pathways. The sequence numbers for all pathways in the first time slot are then calculated. It then searches for packets for the other routes, reserving them for the fast path. It determines the packet sequence for all N routes for future time periods. Using temporary variables, the proposed method estimates the amount of packets and their sequence numbers for each such route for each delivery. The fast route P 1 benefits as a consequence of this, since it is able to transmit packets without having to wait for the rest of the pathways to complete, and all packets arrive in the receiver buffer in the correct order as a result of this. Calculate the total number of packets and the order numbers for the remaining routes as follows:

We also use an example to demonstrate how the suggested method works. Consider a heterogeneous network with three paths: p1, p2, and p3. We begin by sorting these pathways in increasing order by arrival time. Let rtt1=5ms, rtt2=10ms, and rtt3=15ms be the corresponding round-trip times for the three routes, and let the congestion window for all routes be the same 5. For simplicity's sake, no in-flight packets or packet loss on any route. The result of using the proposed scheduler for this scenario is presented in fig 3

Figure 4. Sequencing Logic

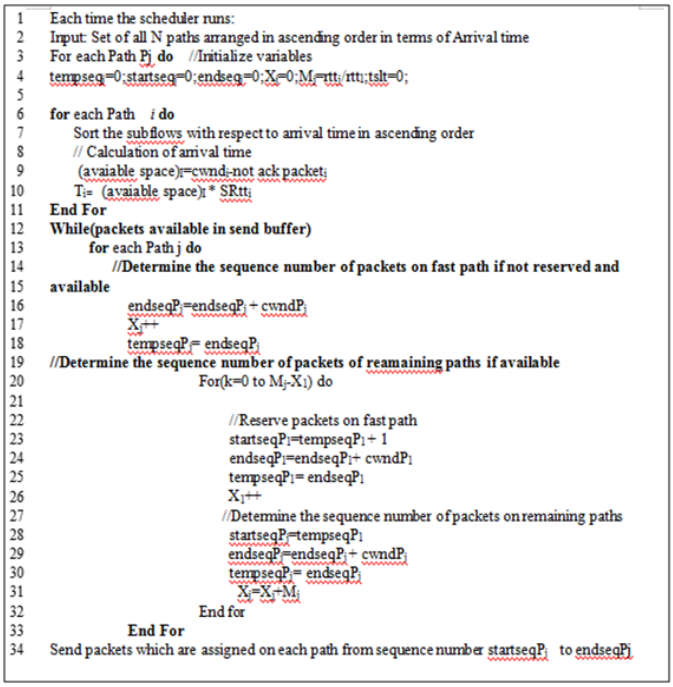


Figure 5. Allotment of packets to respective paths

Time Slots	1--5	6--10	11--15	16--20	21--25	26--30	31--35	36--40	41--45	46--50	51--55	56--60	61--65	66--70	71--75	76--80	81--85	85--90
Paths P1	1-5	6-10	16-20	26-30	36-40	41-45	56-60	61-65	71-75	81-85	91-95	96-100	106--110	111--115	121--125	131--135	141--145	146--150
Paths P2	11-15	NA	31-35	NA	51-55	NA	66-70	NA	86-90	NA	106-110	NA	116--120	NA	136-140	NA	151-155	NA
Paths P3	21-25	NA	NA	46-50	NA	NA	76-80	NA	NA	101-105	NA	NA	126--130	NA	NA	151--155	NA	NA

Indicates that all MPTCP routes are initially accessible at time slot 1 and are ordered in order of arrival time. The FPRS chooses path P1 because it has the shortest arrival time; the amount of packets allotted to it corresponds to the congestion window size. The path P1 is used to send packets from sequence 1 to 5. For the time of rtt1, the congestion window of path P1 becomes unavailable after transmission (5 ms). FPRS chooses the lowest available path, P2, at that point, but before assigning packets to P2, it reserves packets 6 – 10 for path P1 and allocates packets 11-15 to path P2. Now For the duration of rtt2, Path P2 is unavailable (10 ms). So because RTT is 10 milliseconds, FPRS

delivers packets from sequence numbers 11 to 15 over route P2 rather than 6 to 10. (i.e., twice RTT of path r1).. The FPRS expects that route P1 will become accessible in 6-10 seconds and send another window to the receiver. However, packets 6 to 11 are held in reserve for the path P1 and will be sent when the path P1 becomes accessible. For each route FPRS determines the order number of packets ensuring that packets arrive at their destination in the correct sequence and with the quickest time frame. Likewise, the FPRS chooses the succeeding available path with the lowest arrival time, P3, and delivers packets with numbers 21 to 25 in line with the free space in congestion window, before be- coming unavailable for the length of rtt3 (15 ms). Because the RTT gap between Path1 and Path3 is three times, FPRS reserves packets 16-20 on P1. This procedure is repeated until all of the packets have been transmitted. After 5 milliseconds, or time slot 6-10, route P1 becomes accessible and transmits packets from 6 to 10.

In this slot, paths P2 and P3 are not accessible. Path P2 becomes accessible after the following 5 ms, or 10-15, when path P1 has packets 16-20 to send, but before allotting to it, packets 26-30 are reserved for path P1, and packets 31-35 are assigned to path P2.

The transmitter transmits all the incorrect sequence of data packets being sent to the receiver in this fashion, while the receiver gets all packets in sequence due to its limited buffer space. P1, P2, and P3, all begin transmission at the same time. As a result of parallel transmission, there's a risk that several packets from separate routes will end up in the same receiver buffer. After 5 ms, the route P1 transmits the packets (packets 6–11), which are also transmitted by the paths P2 and P3 with current window. As a consequence, certain packets from several paths will arrive in the receiver buffer at the same time, but they won't pose a because the receiver will process them in the correct sequence, there is a HoL blocking issue. If a packet is lost, on the other hand, the FPRS re sends it as soon as the quickest path becomes available.

Unlike the RoundRobin, LowLatency, schedulers, the FPRS scheduler calculates the amount of packets along with their order numbers for each path, allowing them to reach the receiver buffer in sequence . The FPRS is different with respect to existing schedulers, in that it estimates packets for all the paths more accurately than the others. It takes less time to finish than other schedulers because it never waits for the quickest path to send packets to be- come available, like ECF does. The FPRS and BLEST are com- pared in two ways:If the quickest route is not accessible at the time of transmission but can finish the broadcast before another path, the fastest path should be used, BLEST prioritizes the fastest path. As a result, the second most efficient technique of sending packets in order to the receiver buffer is underused. FPRS estimates the number of packets that will be transferred over the fastest route when there is no space left in the congestion window of that route and

that route can complete the transfer faster than the other available routes. The FPRS then allocates packets to the chosen route by by- passing as many packets as the fastest route has projected without queuing for the fastest route.As a consequence, the FPRS utilizes all of the routes' bandwidth and sends data to the receiver buffer in order. It has a greater good put compared to BLEST and can transmit data in less time.

FPRS performs better in means of throughput and download time. The amount of accessible pack- ets and the number of sluggish routes have no effect on its performance. However, because of the packet prediction for each path, this scheduler has a disadvantage in that it necessitates additional pro- cessing. The FPRS predicts the packets that will be sent along that route in the future. Even if it does not have a congestion window available at the time and has a lower arrival than the chosen path.

EXPERIMENTS & EVALUATION

FPRS scheduler is implemented in the MPTCP Linux kernel Neira-Ayuso et al. (2020) in this study, and its result is evaluated to that of other schedulers currently available today. To evaluate the performance of several schedulers three real test beds (4G Wi-Fi test bed, WiFi-WiFi test-bed, and wired-wireless test-bed) are used. Multipathing is made possible by concurrently transmitting data over two networks, Ethernet and LTE/Wi-Fi. As shown in Fig 5-7 these two networks are linked to the receiver network

via two different gateways via a router. The iperf3 client is used to generate traffic on the sender side. In the first test-bed, a laptop (Dell laptop equipped with Intel® core TM i- 7 4590 CPU @ 3.6 GHz and 20 GB of memory) is linked to a server (Intel core i7-7700 processor @ 3.6 GHz and paired with 64 GB of DDR4 RAM.) via Wi-Fi and Wi-Fi, as shown in fig 3. Both have MPTCP enabled Linux Kernels and MTCP versions of 4.19.105 and mptcpv9, respectively. The iperf3 client is used to generate traffic. Each scheduler generates constant bit rate traffic for 200 seconds iterative. As shown in Fig 6, the second

Figure 6. WiFi-WiFi Network Testbed

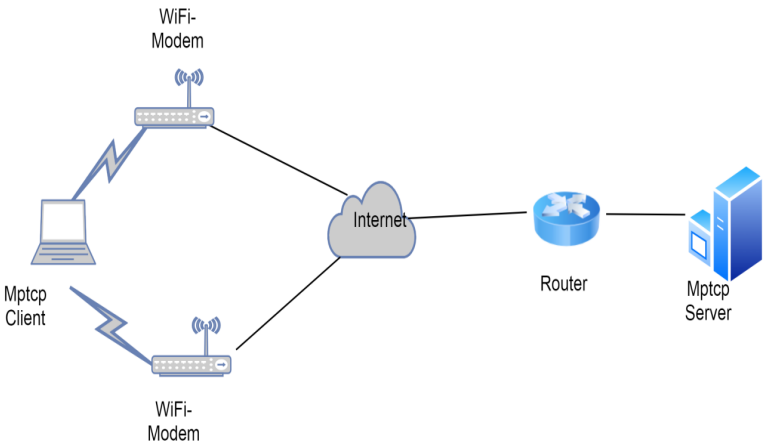


Figure 7. WiFi-Lte Network TestBed

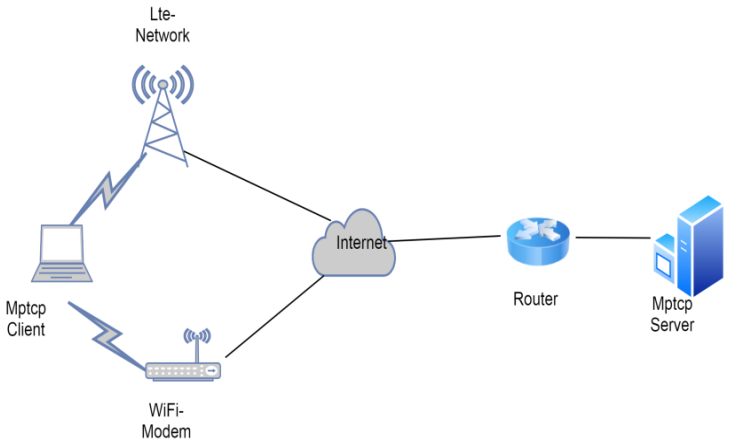
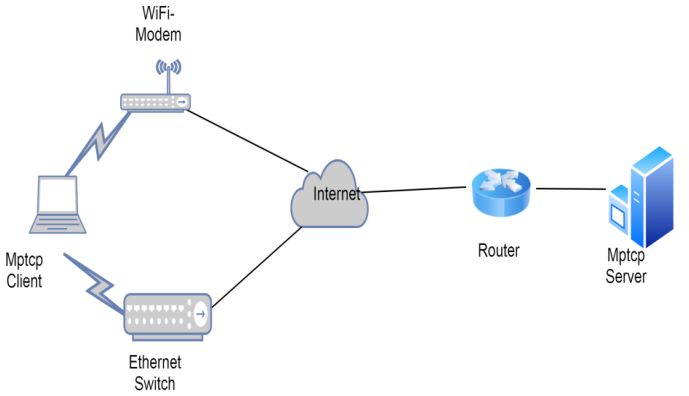


Table 1. Network Specifications

Interface	Rate	RTT
LTE	16 Mbps	70ms
Wi-Fi	15mps	60ms
Ethernet	80mbps	10ms

test bed connects two devices (MPTCP client and MPTCP server) via two interfaces (cellular network (4G) and Wi-Fi). Ubuntu 14.04 is installed on both machines.MPTCP Schedulers generate constant bit rate traffic for 200 seconds by iterative manner, and experiments are repeated many times. The dataset is created by issuing the iperf command from the terminal. These readings are recorded using the SS command. Finally, MPTCP Schedulers are compared using statistical graphical analysis with the R Tool.

Figure 8. WiFi-Ethernet Testbed



In order to accurately compute the route bandwidth and round- trip time, the test-beds are designed in such a way that we must explicitly calculate them, as previously mentioned.

To evaluate FPRS performance in a real-world test-bed, we create different cases by varying the schedulers, test cases, and with different networks as shown in Table 1. Throughput, download time, and path utilization are used as performance metrics for FPRS performance.

The client sends an HTTP request to the server to download the data in all three test-beds. After receiving the client request, the server produces the traffic that is delivered via Iperf. The throughput of all packet schedulers (MinRtt, Blest, Redundant, Roundrobin, and FPRS) over test beds are displayed in Fig 7-9 after successful data transmission in each scenario.

The FPRS scheduler outperforms in every situation, as these figs demonstrate. This happens be- cause the FPRS chooses packets for each path in such a way that they arrive to the receiver in the correct order and with minimal delays.

In this section, we will examine how the Multipath TCP schedulers Perform in regards of download time. Figure 10 shows the download time for each scheduler for a variety of data volume configuration. It has been highlighted that, even though scheduling approaches may differ on the delivery time-

frames, they all ultimately supply the data. In a 4K,200K,300K,1000K, and 256MB data volume

scenario, the FPRS scheduler gives the quickest delivery time of roughly 34 milliseconds, 40 millisec- onds, 55 milliseconds, 100 milliseconds, and 32 seconds. Because of the relationship between these two items, this dilemma occurred. Once packets become out of order owing to the utilisation of nu- merous networks, the RTT values begin to grow and become less appealing to the scheduler. Thus, the Scheduler, which contains the fastest network download time of the four tested scheduling strategies, may bypass heterogeneity like the FPRS. The data is delivered in 42 seconds using the round-robin mechanism. It has poor reaction times to the failure and recovery of interfaces, as it continues to send data to interfaces even if they're afflicted with long round-trip times. The most inefficient overall deliv- ery time (approximately 52 seconds) is accomplished using the redundant approach. This is due to the surplus data eating up space. FPRS has a shorter flow completion time than all other packet schedulers,

Figure 9. Throughput Comparison in Homogeneous Networks

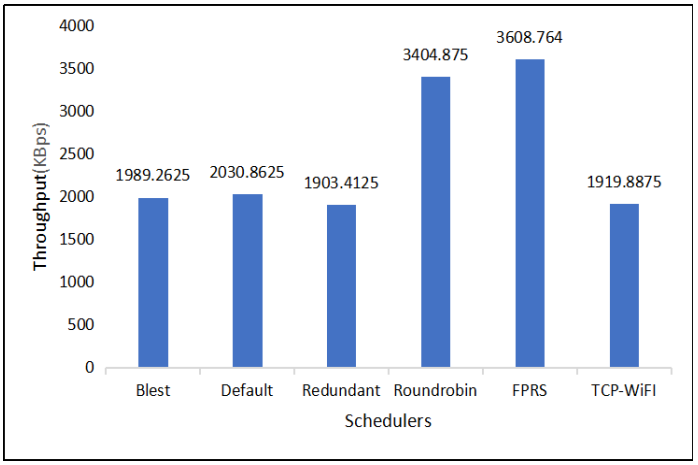


Figure 10. Throughput Comparison in Heterogeneous Networks

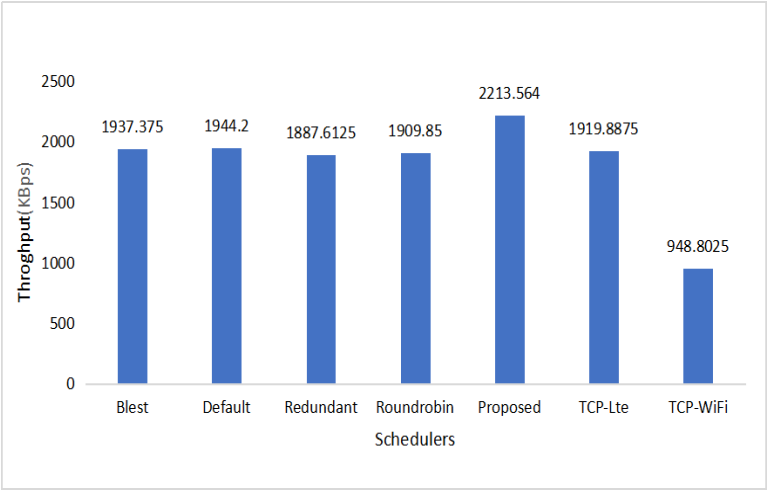


Figure 11. Throughput Comparison in Heterogeneous Networks

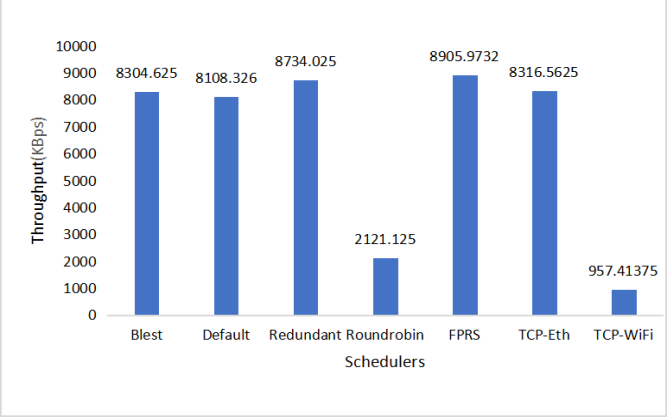


Figure 12. Download Time of Schedulers with different data volumes

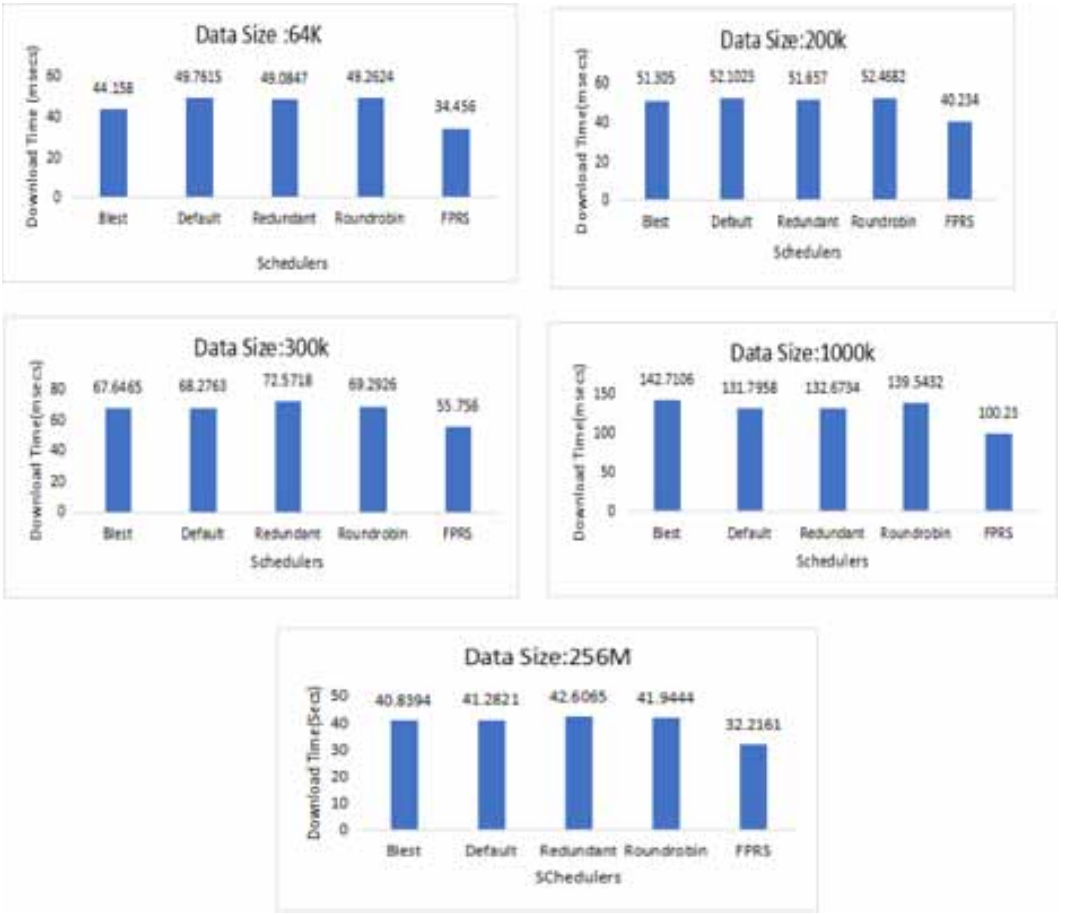
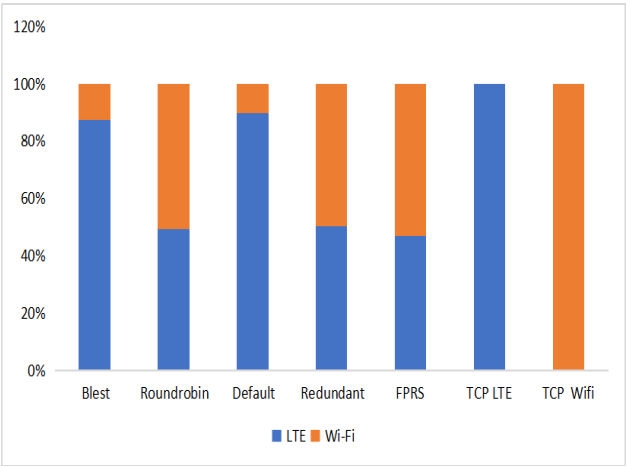


Figure 13. Path Utilization of Schedulers in Wifi-Ethernet Scenario

Figure 14. Path Utilization of Schedulers in Wi-Fi-Lte Scenario



DISCUSSION

When contemplating the architecture of a new multipath protocol's scheduler, path heterogeneity should be seen as the norm rather than the exception, since it is crucial to the scheduler's ultimate aim of op- erating in millions of Internet devices independent of the applications running on top. Even though the destination host has just one Multipath TCP subflow, it may take various routes, leading to varying latency, bandwidth, and loss. Since it's only important to look at various network routes when the network has paths belonging to multiple technologies, such a smartphone with WLAN and a cellular network interface, it's unnecessary to examine path heterogeneity. Path heterogeneity may cause the receiver to get blocked by a host of hosts, which might impair MPTCP's overall performance.

Also to alleviate HoL-blocking, we have developed and thoroughly tested alternative scheduling methods. Though all options delivered satisfactory results in certain cases, none was effective across all situations and with all apps. And thus we have devised a new kind of scheduler, FPRS, which makes use of Fast Path Reservation. Unlike prior solutions, FPRS (Fast Path Reservation Scheduler) analyses the potential HoL-blocking value to minimise, and uses it to schedule packets across all subflows according to their RTT gaps. They reorder packets at the sender side, making sure they arrive in sequence at the recipient. Thanks to this, we were able to create a more comprehensive, proactive scheduling metric to get rid of any punishment.

We next tested FPRS in a real network, as is described in Section 4. By conducting a comparison between FPRS and schedulers, we found that FPRS outperforms all algorithms in each of the situations given, accomplishing its objective of decreasing the occurrence of HO-blocking and thus reducing false retransmissions. These improvements lead to more accurate application performance estimates, shorter completion times, and a reduced end-to-end latency.

We think that FPRS will adopt the correct approach to scheduling for diverse situations in the future. Even yet, further analyses that take into account other forms of diversity, such as alternative network access methods, diverse application performance measurements, and other mobility situations, are required.

CONCLUSION

A novel MPTCP packet scheduler, the Fast Path Reservation Scheduler (FPRS), is proposed in this paper, which provides in- order delivery while still offering enhanced throughput., reduces the HoL stalling problem, has a shorter completion time, and makes use of all available paths, among other things. The FPRS scheduler picks packets to every path in a such a way that they reach in the

receiver buffer in the sequence in which they were sent and with the shortest completion time that is possible. In this study, We evaluated the FPRS packet scheduler with other schedulers. Against all other Linux kernel schedulers by using a variety of network interfaces. In comparison to prior schedulers, It out- performs them by solving the fundamental problems of out-of-order data packet delivery and Head Of Line blocking.

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