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Improvement Possibility of Typical Protocols over High Speed wireless Networks

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***Abstract*—High speed networks such as Fourth Generation (4G) of cellular communication systems is a technology emerging from future wireless networks. In recent years, many researchers and scientists worldwide have been working on government and business funded projects, whose goal is an efficient wireless network, borne from all current technologies. By adapting new solutions for these enhanced telecommunications, superior quality, efficiency, and opportunities will be provided where wireless communications were otherwise unfeasible. Some researchers define 4G as a significant improvement of 3G, where current cellular network's issues will be solved and data transfer will play a more significant role. For others, 4G unifies cellular and wireless local area networks, and introduces new routing techniques, efficient solutions for sharing dedicated frequency bands, and an increased mobility and bandwidth capacity. One of the main solutions to improve the performance of new wireless communication systems is by improving TCP (Transmission Control Protocol) performance. This article investigates the possible practical solutions to enhancing the performance of TCP over 4G systems.**

***Index Terms*— 4G, protocol, wireless networks, cellular system.**

I. Introduction

Most data applications are built on top of a TCP, since TCP provides end-to-end reliability via retransmissions when IP packets are missing. TCP was originally designed for wired networks, where packet loss was due to network congestion, and consequently, the TCP window size was adjusted upon detection of the loss. However, packet loss within wireless networks is mostly due to bad radio conditions, and not network congestion. Errors in the air-link are often caused by several factors e.g., interference from other sources, fading due to mobility, or scattering due to a large number of reflecting surfaces [1]. The performance metric of TCP in a cellular environment is the average throughput, which is the same as wired networks.

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The average throughput in the cellular case does not only depend on network congestion, but may also be attributed to other factors, such as the bit error rate of the wireless medium, the cell handoff time, and the cell resident time [2]. TCP is typically used in wired communication systems with very small error probabilities. However, the error characteristics of wireless channels differ significantly from that of wired channels. Therefore, TCP gives very poor performance if it is directly applied to a wireless communication system. Wired channels are characterized by miniscule packet-loss probabilities and randomly spaced errors. In contrast, wireless channels are characterized by time varying packet-loss probabilities that are generally much larger than for wired channels. In addition, errors are typically bursty in wireless channels [3]. Meanwhile, 4G wireless users should not see any difference between a wired and a wireless network, and will have multiple connectivity options. For these reasons, we should seek to provide a new TCP, which can meet these requirements. An instant way of improving TCP performance would be to modify the TCP itself, since it is the inherent assumptions of TCP that are the cause of its poor performance within a wireless environment [4].

Unfortunately, wired and wireless networks are significantly different in terms of bandwidth, propagation delay, and link reliability. These differences imply that packet losses are no longer mainly due to network congestion, as they may well be due to other wireless specific reasons. Actually, in wireless LANs or cellular networks, most packet losses are due to high bit error rates in wireless channels, and handoffs between two cells. Meanwhile, in mobile networks, most packet losses are due to medium contention and route breakages, as well as radio channel errors [5]. Therefore, even though TCP performs well in wired networks, it suffers from serious performance degradation in wireless networks, especially when networks have a high rate of data transferring reach over a bandwidth of one Gbps (Giga Bit per Second).

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TCP flow control was originally governed, simply by a maximum allowed window size, advertised by the receiver, and a policy that allowed the sender to send new packets only after receiving an acknowledgment for the previous packet [6]. It is also true that protocols, such as TCP, perform very badly over wireless links – lost or delayed packets can signal to the TCP that congestion is taking place and cause flows to slowdown. Wireless links – with their unpredictable losses and packet delays - can cause the TCP to assume network congestion is taking place, even when the wireless link is well below its full capacity [7]. Numerous studies have found that TCP supports only wireless internet access very inefficiently [8]. The key problem is that wireless channel errors lead to frequent expirations of the TCP's retransmission timer, which is then interpreted as congestion by the TCP [9]. In addition, most data applications are built on top of TCP, since TCP provides end-to-end reliability via the retransmissions of missing IP packets [1]. Furthermore, TCP was originally designed for wired networks where packet loss was due to network congestion, and hence, the TCP window size was adjusted upon detection of the loss. However, packet loss in wireless networks is mostly due to bad radio conditions and not network congestion.

This article presents a survey on the possibility of improving TCP performance over 4G cellular communication systems, including detail and characterizations of each practical approach that is expected to be used. The remainder of the paper is organized as follows: Section II describes the performance of TCP over Wireless Networks. Section III will present the approaches to improving TCP over 4G systems, and finally, our conclusions and discussions will be presented in Section IV.

II. TCP OVER WIRELESS NETWORKS

Given the expansion of wireless technologies and the recent propagation of movable user equipment, there is a perceived and accumulative attractiveness of wireless environments, such as Wireless Local Area Networks (WLANs), Wireless Wide Area Networks (WWANs), and mobile ad-hoc networks. In WLANs, such as Wi-Fi, or WWANs, such as 2.5G, 3G, or 4G cellular systems, mobile hosts connect via an access point or base station that is connected to the wired part of the network. Unfortunately, wireless and wired networks are dramatically dissimilar in their parameters of link reliability, bandwidth, and delay time of propagation [10].

In mobile and wireless networks, there are several challenges that are associated with wired networks, because wireless networks have several essential adverse features that will considerably weaken TCP performance, if no actions are taken. These features involve mobility, link asymmetry, and channel errors.

Connection Asymmetry

The wireless link between a mobile terminal and base station is naturally an asymmetric link, because mobile terminals have restricted power, capability of processing, and limited buffer space.

Channel Errors

In wireless links, comparatively high bit error rates are expected, due to the fading of multipath and shadowing that may damage packets during the data transfer process, leading to a wide loss in TCP components, such as segments or acknowledgments.

Mobility and Handover

Cellular systems are characterized by handovers, due to the user's mobility. Handovers usually cause short-term connection interruptions, resulting in missing packets and adding extra delays over network pipelines.

Theoretically, TCP is independent of underlying layers, and if the underlying layers reduce reliability, then for the wired region (which TCP was first intended to work on), TCP will exhibit some of its deficiencies. However, wireless networks are known for their high probability and large numbers of random errors and irregular connectivity of links. In addition, the congestion control mechanism interprets packet loss as a sign of congestion. In reaction to these missed packets, some TCP versions decrease the size of the congestion window and the flow rate. As a result, a dramatic collapse in TCP performance and throughput can occur. Obviously, users of mobile equipment can dramatically affect the throughput of the TCP, because of mobility features and handover possibilities, which may frequently cause connection interruptions [11].

Commonly, when an IP packet is sent on a wireless link, the layer of IP sees the available capacity, delay characteristics, and amount of loss rate that varies over time. The use of accessible link layer control techniques, such as retransmission scheduling, power controlling, adaption of flow rate, and forward error corrections, permits balance between loss, latency, and capacity. However, it is not easy to reach the constant level of low latency, low loss, and high capacity, which represents the main characteristics of wired links.

For most TCP variants, the congestion control mechanism is believed to adapt to the style of collective turbulences within the wired networks, where accessible bandwidth changes accord to cross traffic, irregular routing, changing capacity, and delays, which are initiated by constant values of queuing and propagation delays [12].

If TCP is used within a cellular infrastructure, performance in both end-to-end throughput or in the employment of radio links is frequently very poor. This is because the self-motivated characteristics of wireless links and TCPs do not fit well together. Working on the problems of TCPs over wireless links, represents the main objective to achieving a good, or at least acceptable, level of end-to-end throughput and an effective use of radio links resources, in parallel with small fluctuations to current infrastructure and protocols. TCP strategy over wireless networks, takes into account the natural individualities of the wireless network and its requirements. For example, satellite networks involve large propagation delay, and ad-hoc networks are without an infrastructure. The trouble is that all wireless networks should face a large BER. In wired-wireless networks TCP design, one of the main objectives is to identify the reason for packet loss. Some developments target the discovery of explicit techniques to notify the TCP source side of the reason beyond dropping of the packet, whether it is congestion or random error events [13].

III. Possibility to Enhancing TCP in 4G

The high rate of data, that is expected for future 4G systems, along with the predicted services provided by this generation, requires strong protocols that are able to overcome the problems and challenges of wireless networks, such as bit error rate, asymmetry between base station and mobile host, and handover possibilities. In addition, these 4G systems (e.g., Long Term Evolution - LTE and LTE-Advanced) support a good concept of Quality of Service (QoS) on radio and transport networks. However, no flow control mechanisms are supported, which may cause some dropping of packets during congestion periods at terminals or nodes [14]. Various methods have been suggested to optimize the performance of TCPs over 4G networks. These methods can be characterized as TCP improvement approaches or the use of layer restrictions. Improving TCPs generally involves approaches based on end-to-end TCP variations, link level, or the splitting of TCP connections, with assistance of intelligent agents.

Split TCP Connection

The wired part of any wired-wireless network has more reliability than the wireless part, concerning connection bandwidth capacity and error rates. The solution is a split connection, trying to improving TCP performance via split TCP connections in to two parts within the base station.

But the TCP connections between the mobile host and the base station are adjusted for the wireless link. Base station design is a very serious point, and any approach based on proxy puts an explicit or implicit intelligent agents at all base stations to detect losses in packets in wireless connection, also it takes other equivalent activities (such as duplicating acknowledgments) to guarantee the sender of a proper TCP response.

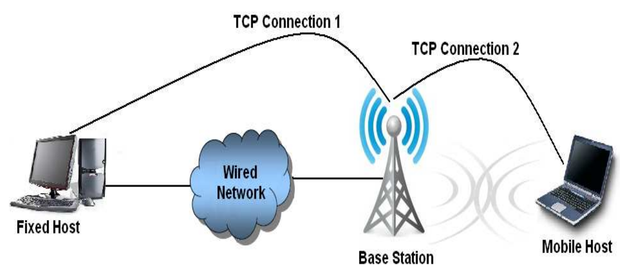

Fig.1 Splitting TCP connections into two parts

The splitting approach attempts to protect the wireless part from the fixed part in the network by isolating the flow control within intermediary base stations for cellular networks (or routers), where wireless activities have the smallest effect on the fixed network. The intermediary base station acts as a wireless terminal for the fixed parts, and all hosts connect with the intermediary base station individually, with no need to acknowledge the other end [13]. I-TCP (Indirect-TCP) [15] is a protocol proposed on the concept that the TCP connection, between any machine on a fixed network, and the mobile host, must be split into two separated connections. The first is between the base station and the mobile host within the wireless portion, and the second is between the fixed host and the base station within the fixed network. As illustrated in Fig. 1.

When a segment is transmitted to a mobile host; first, it is received by the base station and 'ACK' is sent to the fixed host.

Then, the segment is forwarded to the mobile host. When the mobile host travels to another cell within the connection, it establishes with the fixed host, and then, full information of connection (kept at the most recent base station) will be transferred to the next base station.

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The fixed host is not actually informed of this process, and is not affected whilst this switching occurs. Furthermore, when the end-to-end connections are split, the TCP connection for the wireless portion is able to use some variation of the wireless link aware TCP, where it is tailor-made to handle wireless link errors and possible handover disruptions [15].

M-TCP is another split connection approach. It is based on dividing the TCP connection between the mobile host and the fixed host into two parts. The first is between the base station and the fixed host, whilst the second is between the mobile host and the base station [16]. M-TCP differs from I-TCP because it manages to preserve the end-to-end semantics of the TCP. In addition, M-TCP is proposed to operate on the architecture of the underlying three levels, which are shown in Fig. 2.

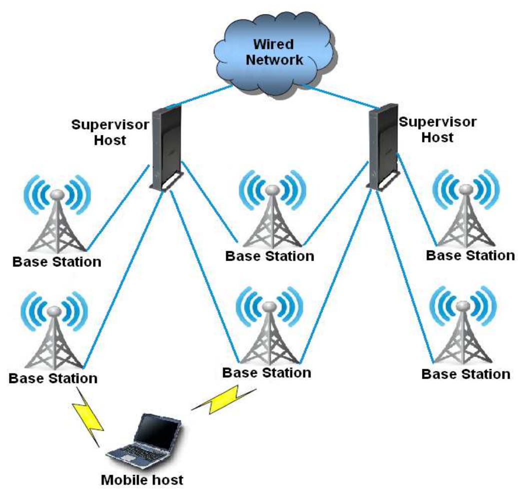

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Fig.2 M-TCP underlying architecture

The mobile host connects via a cell with the base station. There are many base stations under the control of the supervisor host, which serves as a gateway to communicate with the wired medium. The developer of this approach had two specific aims. The first was that base station functionality could be transferred to the supervisor host, thus reducing network costs, as one supervisor host would be in control of the many base stations.

The second was the possibility of significantly reduced handovers occurrences, as the mobile host roaming between cells would not need to execute handovers when the two cells were controlled by the one supervisor host.

Link Level Solution

The link level solution attempts to provide a link level with more reliability, in order to shield the network's transport layer from wireless actions. The well-known reliable procedures models are known as link level Forward Error Correction (FEC), link level Automatic Repeat Request (ARQ), or Hybrid ARQ (HARQ). Through a native resending of lost packets, the ARQ technique offers more reliability the link layer.

Meanwhile, the FEC mechanism can increase the probability of packet delivery, by accumulating the various redundancies of the transmitted packet. Obviously, the reliability level of the link layer depends on the ARQ persistency and the FEC scheme redundancy [10]. The Snoop protocol was one of the earlier link layer solutions that introduced an extra snoop agent at the base station of the wireless medium [17]. Balakrishnan et al., attempted to enhance TCP performance by revising the network layer software on the base station, whilst preserving the TCP's end-to-end semantics.

The name 'Snoop' implies that it is adding a snooping element to the network layer that is able to observe each packet that passes through the base station, in any route [18]. The Snoop agent observes all packets corresponding to the TCP's connection in two ways, and buffers the unacknowledged packets by the TCP receiver. Furthermore, the Snoop agent maintains a timer for the sent packets, since lost packets may be noticed by both the incoming duplicate ACK number, and the timer's expiration. The highest benefit of using a link level protocol for packet loss recovery is that it fits logically into the layering organization of network protocols and works independently of other higher layers [11]. However, whilst TCP handover performance may be enhanced, substantial overheads are suffered for preserving the base station group multicast and the transferring state from one base station to another.

End-To-End Solution

Another solution to improving TCP performance is by using an end-to-end approach, where the finale hosts contribute to flow control. The sender is responsible for adjusting the congestion within the network, whilst the receiver provides feedback, which reflects the condition of the network. This procedure is shown in Fig. 3. In the end-to-end approach, the ability to correctly analysis the accessible bandwidth represents the larger challenge of discovering the best performance.

The end-to-end approach has a congestion control mechanism that is realized by two methods, namely proactive and reactive. In the proactive mode, the congestion control mechanism obtains feedback from the network guide to the sender, thus reallocating resources of the network to avoid congestion. Meanwhile, in reactive mode, the congestion control mechanism relies on the sender to rectify the congestion window if the network's situation is peripheral or has a cross over threshold [13]. Several augmentations are suggested for the congestion control of a standard TCP. Several of these schemes seek to expand the TCP performance of unreliable networks; including wireless.

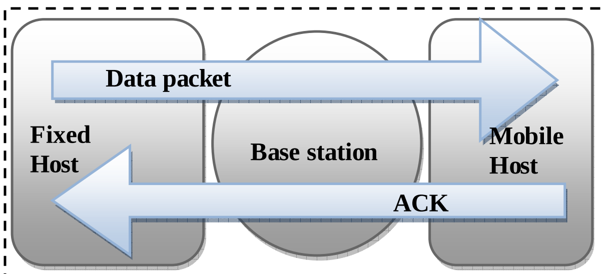

Fig. 3 End-to-end connection of a wireless TCP

Explicit Congestion Notification (ECN) is a perfect example of this end-to-end approach, in which routers report congestion to the TCP sender using an IP header. ECN supposes that dynamic queuing management is arranged at the central group of routers, allowing the discovery of congestion, before loss occurs and before the queue overflows [19]. Another end-to-end approach method, which is similar to the ECN technique, in which an influenced queuing management pattern is recognized at the routers to separate random loss from congestion losses [20]. The main concept of this protocol, called TCP-Casablanca, is to de-randomize the losses of congestion, so that the spread of congestion losses changes from that of random losses resulting from the wireless network. To achieve this, the TCP sender signs several of the sent packets; and when congestion occurs, routers drop those packets first. Simulation results prove that TCP Casablanca recognizes congestion losses with an accuracy of up to 95%, and 75% for wireless losses.

IV. Conclusion

This article illustrates the ability to improve standard TCP variants to operate over 4G systems with more efficiency and reliability. Most protocols, such as TCP, perform very badly over wireless links and cause lost or delayed packets.

Wireless links, with unpredictable packet losses and delays, can cause the TCP to assume that network congestion is taking place, even when the wireless link is well below its full capacity. There are many solutions to improve TCP over 4G cellular communication systems during the handover period or to increase the TCP window size. However, the drawback is that it requires modification of existing TCP protocols. TCP actually provides a very good service and reliability is paramount. Mobile high speed links is an area of on-going research that needs to be addressed, in order to take into account the particular transmission characteristics introduced by the network.

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