Throughput Enhancement on the Uplink of 3G Cellular Systems

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Abstract - The third generation (3G) wireless network is envisaged as the next generation wireless solution for meeting the demand of its users. It promises to provide wireless access to multimedia applications at rates up to 2Mbps. In contrast to wired links, wireless links are unreliable; they exhibit a varying bit error probability and temporary outage periods, during which the bit errors are strongly correlated. From the application point of view, error-prone channel conditions are recognized by a reduced throughput, higher loss rate, higher jitter and/or higher delay. Instead of attempting to tolerate the unstable service from the physical layer such as adaptive applications, we introduce a new mechanism that helps to stabilize the QoS in terms of throughput, loss rate, jitter and delay at the data link layer. We resorted to this mechanism within the data link layer, because in that way higher layer protocols do not have to be changed at all. Thus, the same protocols as for wired networks can be used. The problems of intermittent disconnection, high error rate in wireless networks can cause degradation of protocols and compromise the QoS (Quality-of-Service) guaranteed to the users. So, there is a need for adaptive protocols, which, on determining the current adverse wireless network conditions, adapt themselves in order to overcome these changes and reduce their effect. Our focus in this work has been to design adaptation techniques for media access control (MAC) protocol since their capability to adapt to the adverse effects of wireless conditions can make the high-level network protocols less susceptible to the changes in the wireless conditions. We have chosen SMPT (Simultaneous MAC Packet Transfer) technique for our study. Our results show that there is increase in throughput using the adaptive techniques mentioned in this report.

I. INTRODUCTION

One of the driving forces of the next generation of wireless communication and computing networks is the promise of high-speed multimedia services. Third Generation (3G) systems, such as the International Mobile Telecommunication System 2000 (IMT-2000) network (formerly known as the FPLMTS Future Public Land Mobile Telecommunication System) and the Universal Mobile Telecommunication System (UMTS), promise to provide multimedia services to mobile and fixed users via wireless access to the global telecommunications infrastructure. The IMT-2000 is a universal, multifunction, globally compatible digital mobile radio system that plans to integrate all traffic types and all wireless systems under a common set of formats. The UMTS is a similar global wireless solution, and is being standardized by the European Telecommunications Standards Institute (ETSI). Among the requirements for the third generation systems is the ability to support multimedia traffic. Ultimately, 3G are expected to include capabilities and features such as: Enhanced multimedia (voice, data, video, and remote control), Usability on all popular modes (cellular telephone, e-mail, paging, fax, video conferencing, and Web browsing), Broad bandwidth and high speed (upwards of 2 Mbps), Routing flexibility (repeater, satellite, LAN), Operation at approximately 2 GHz transmit and receive frequencies, Roaming capability throughout Europe, Japan, and North America. The 3G networks are expected to support a variety of voice and data services (at high rates) and yet maintain equality. However, as against the wired channel wireless link is much more error prone. The performance degradation of wireless communication can be caused both by poor wireless environment and large number of wireless users that share the communication medium. Thus, providing QoS to the application becomes an important issue. So, adaptive protocols are needed which, depending on the adverse wireless conditions, would adapt themselves to mitigate the effects of these changes. The adaptation can be provided at any layer of the OSI reference model. In this work, we propose adaptive techniques for improving the performance of MAC protocols through awareness of mobile communication environment. We have chosen MAC layer because being closer to the physical layer, it has a better idea of channel conditions and thus, it can adapt easily and quickly. Also, its adaptation can make high-level network protocols less susceptible to changes in the wireless conditions. The MAC protocols proposed for CDMA systems include Multidimensional PRMA with prioritized Bayesian Broadcast [12], Wireless Multimedia Access Control with Bit Error Rate Scheduling (WISPER), WCDMA MAC protocol [10], Simultaneous MAC Packet Transfer (SMPT) [13]. Most of these protocols use appropriate scheduling algorithms and reservation of traffic types to improve performance under different types of multimedia services. These protocols differ in the way they allocate resources (codes) to the mobiles. But none of them is adaptive to the channel conditions. Our effort in this work has been to make the existing scheme, SMPT, adaptive. Four different SMPT approaches based on the MultiCode CDMA (MC
CDMA) [13] are introduced for the QoS support of uplink communication in wireless networks. SMPT enabled wireless terminals transmit and receive on multiple CDMA channels. Two approaches, namely Slow Healing and Fast Healing, try to stabilize the wireless link by using parallel channels for retransmissions of corrupted packets. These approaches are well suited for rate adaptive video streams. The other two approaches, namely Slow Start and Fast Start, are well suited for video streams without any rate control. These approaches use the parallel channels whenever they detect a good channel state. All approaches can be applied in distributed systems. In order to reduce the loss rate seen by higher protocol layers Automatic Repeat ReQuest (ARQ), Forward Error Correction (FEC) or Hybrid ARQ can be used to transmit packets. These four approaches were limited to an SMPT algorithm which is only based on ARQ (e.g: retransmits the original packets). On the other hand we have introduced that using an additional FEC or a mixture of ARQ and FEC (Hybrid Type I,II) channel probes during channel impairments can further improve the performance of uplink of wireless networks.

A. Medium Access Control Protocol (MAC)

In a wireless system that consists of a number of mobile terminals that transmit traffic of any type on a shared medium to a centralized base station, a procedure must be invoked to distribute packet transmission among all users. This procedure is known as a medium access control (MAC) protocol. MAC protocols are often classified according to their method of resource sharing, as well as their multiple access technology. The resource sharing methods include dedicated assignment, random access, and demand-based assignment. Dedicated channels assign each user a pre-determined and fixed allocation of resources, regardless of the user's need to transmit. Dedicated assignment schemes are appropriate for continuous traffic, but can be wasteful for bursty traffic. On the other hand, random access channels, allow all users to contend for the channel by transmitting as soon as packets are available to send. Random access is suitable for bursty data traffic, but is not desirable for delay-sensitive traffic. Demand based assignment schemes assign resources according to requests, or reservations, submitted by users. Once the requests are transmitted (using either dedicated or random access channels) and processed, users can be assigned resources according to the results. Demand-based channels are useful for variable rate traffic and the hybrid conditions of multimedia traffic. However, the additional overhead and delay caused by the reservation process can degrade performance. In addition to the resource sharing method, the multiple (or multi) access scheme of a MAC protocol establishes a method of dividing the resources into accessible sections. Three accepted methods for resource division are Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA). FDMA schemes divide the resource into portions of spectrum, referred to as channels. TDMA divides the resource into time slots. Finally, CDMA divides the resource into a collection of codes through which assigned users can co-exist on the same channel. First generation mobile systems (late 1970s) and early second-generation systems, such as the Advanced Mobile Phone System (AMP), used FDMA schemes to support analog communication. For second generation systems (began in 1990s), the most used multi-access schemes have been TDMA and CDMA. Wide-band CDMA (WCDMA) has been chosen as the basic radio-access technology for 3G networks [5], [14].

B. Overview of CDMA

In a CDMA system, the symbols, which carry information bits, occupy a bandwidth more than the minimum needed for the transmission [1], [2]. There are two techniques to achieve this, namely, Direct-Sequence (DS) and Frequency-Hopping (FH) spread spectrum. In this report, we are only concerned with the first technique. In a receiver-oriented DS-CDMA system [14], Base Station (BS) may have several receivers, each of which listens to a specific code. A mobile host (MH) transmits information bits by applying a code to them to generate symbols covering a large bandwidth. Only the receiver, which listens to this code, can recover the bits from the symbols; other receivers perceive them as noise. It is important that two mobiles should use different codes for transmission at the same time; otherwise, the receiver cannot distinguish them. Even if a bit transmitted by a MH is spread with a code different from any other code used at the same time, it may still be corrupted because of multiple-access interference (MAI) caused by the bits simultaneously transmitted by other MHs generate some level of noise on the intended receiver.

II. RELATED WORK

Recent research has shown that Simultaneous MAC Packet Transmission gives guaranteed QoS over uplink of 3G cellular systems. The idea behind SMPT approach is that CDMA systems allow multiple channels in parallel as long as the total number of used channels does not exceed a specific threshold. In contrast to common wireless CDMA systems, where each wireless mobile terminal uses a single channel for all supported flows of a multimedia application, this approach allows the mobile to allocate multiple channels, assuming a CDMA system which has more channels than users. In this approach, the sender transmits a higher protocol data unit within a given delay bound. The segment is fragmented into data link packets. It is assumed that allowed transmission time for a higher protocol entity is a multiple of the data link packet transmission time. As long as the wireless channel is error-free, packets can be sent sequentially on one channel. In case of an error prone link, ARQ transmissions of data link packets are done within the code domain using multiple channels. Furthermore, if it is assumed that fading durations on the wireless link are smaller than the transmission time of an entire transport segment, then MAC level retransmissions on multiple channels are performed only if the wireless link is less error prone to achieve a high spectral efficiency. The advantage of SMPT is that it can recover from gaps caused by errors on the wireless link within a given TCP or UDP segment. Multiple channels are used by the mobile at its own
discretion. Using multiple channels in parallel, however, can degrade the overall system capacity, because each additional active channel will lead to a degradation of the signal-to-noise ratio (SNR), which results in high bit error probabilities. Thus, multiple channel usage must be avoided when the channel is bad. There are many possible ways to use multiple channels. The two different types of approaches are Self-Healing and Start-Up (as an example we demonstrate the transmission of 16 link packet data units (LPDUs)). Self Healing is only used if sequential transmission (using one channel) falls behind due to channel errors. The Self-healing mechanism reduces the accumulated delay jitter using the capacity to send on additional channels. There are two main approaches to Self-healing process [13].

A. Fast Start
The Fast Start is depicted in Figure 1. In our example this leads to a successful transmission of the first eight packets in the first two time slots. After each uplink time slot the successful transmitted LPDUs are acknowledged. When the bad phase starts at time slot three the mechanism will send four further packets (9,10,11,12). Even if the channel state is bad, the sender transmits on all parallel channels, because the sender has not realized the changed state of the wireless channel, yet. If no acknowledgment is received before the LPDUs are scheduled for time slot four, the sender stops the Fast Start phase and changes to the Probing phase. Probing phase stops if this LPDU is transmitted successfully and an acknowledgment is received. Simultaneously the sender switches back to the Fast Start phase using all parallel channels.

B. Slow Start
The Slow Start approach is depicted in Figure 2. In contrast to the Fast Start method it will use the channels in a more moderate way. Using the Slow Start approach the sender starts to transmit the first LPDU. After having received the acknowledgment for this LPDU, it assumes to be still in a good channel state and transmits the next time two LPDUs in the next slot and so on. When the bad channel begins, the sender will not receive the acknowledgment for the these LPDUs. In this case, like the Fast Start approach, the sender switches to the Probing phase. After recognizing a good channel state again it starts to build up the ramp once again until all LPDUs are transmitted.

C. Fast Healing
In contrast to the Start Up approach, Self Healing is used only if the sequential transmission (using one channel) falls behind due to channel errors. The Self Healing mechanism reduces the accumulated delay jitter using the capability to send on additional channels. There are two main approaches of the self-healing process. The Fast Healing (see Figure 3) approach uses all available resources immediately after detecting the good channel state.

D. Slow Healing
Slow Healing process uses the resources incrementally (see Figure 4). For both approaches, we assume that only one channel is used after any error on the wireless link is detected. The goal of our Self Healing SMPT mechanisms is to repair the accumulated delay jitter always after an error prone link. It will never send LPDUs preventively like it is done with Start Up approach. It seems that the Slow Healing approach has the best capability to adapt itself to the conditions in the wireless cell.

III. PROPOSED SMPT APPROACH
The SMPT technique uses single channel during probing mode i.e. when the channel is bad. The packets sent during the probing mode are sent without using any channel coding
scheme. Depending on how long the probing mode continues, the packets can suffer increased delays. This is undesirable especially for real-time data traffic. Our idea is to use two channels during probing mode (see Fig 5). The goal is to increase the goodput even during the bad channel mode. One first channel, send an uncoded packet. On the second channel, send the FEC coded packet. (We used rate=1/2 FEC scheme in our simulations). Suppose N th packet is corrupted. During probing, transmit two packets within a given time slot, using two channels. Applying FEC coding to Nth packet, we get two packets N(a) and N(b). On the first channel transmit (N+1)th packet and on the other, transmit N(a) packet. Now four possibilities arise. If only FEC coded packet is received correctly since the uncoded packet is received corrupted, thus this means that the channel is bad and only the FEC coded packets can be transmitted correctly. Since FEC coded packet was transmitted successfully, thus we are able to increase the throughput during the bad channel state. So, we continue using the two channel probing mode. (In the next slot we send, (N+1)th packet and FEC coded N(b) packet. In the next slot we will send, (N+2)th packet and FEC coded (N+1)(a) packet. Then in next slot we will send (N+2)th packet and FEC coded (N+1)(b) packet). This continues until both are received correctly or both received incorrectly. If both the packets are received correctly since the uncoded packet is received correctly, thus this means that the channel has become good. Thus, there is no need for coding and the protocol should revert back to the normal mode and start with the transmission of Nth packet. If both the packets are received incorrectly since even the FEC coded packet gets transmitted corrupted, so this means that channel condition is very bad. So, either continue sending the same set of packets or start using higher FEC scheme. If only the uncoded packet is received correctly this case is not probable because if FEC coded packet is corrupted then uncoded packet will be corrupted too. We do not use more than two channels in the probing mode because using more codes can increase the level of interference in the bad state of the channel. And we have to use at least two codes for this idea to work. We have used NS-2 simulator for proving our approach. The results obtained and the comparison between the existing SMPT techniques and the proposed technique are depicted in table 1 below.

IV. CONCLUSION

Simulation results show that the proposed technique has shown improvements in good put compared to simple SMPT technique. We had expected that the difference would diminish as the number of mobiles increases, as more mobiles would have added more interference had made the channel more error prone. And thus the packets sent on the second channel would have added more interference and would have been thus corrupted. But the simulation results showed that the difference actually increases with increase in the number of mobiles. This lead us to further thinking and provided further insight into the understanding of our idea. As the number of mobiles increases, the channel becomes more error prone and thus the erroneous phases are long and thus we are able to transmit more packets during the erroneous phase. The reason the point when the number of mobiles (interference level) would become so much that even the FEC coded packets get corrupted. We have demonstrated that MC-CDMA (Multi-Code CDMA) based 3G wireless communication systems can benefit from the introduced adaptations in SMPT mechanisms. The proposed schemes can play important role in improving performance of the point-to-point links in the wireless ad-hoc networks and wireless mesh networks as well.

V. FUTURE WORK

Our work can be extended in several ways. A connection admission control (CAC) policy can be implemented for a MAC protocol to determine if a new connection can be given channel access without violating the QoS requirements of the existing conditions. The mobile nodes were considered stationary during the current simulations. The simulations could be performed with more complicated topology taking into account the mobility of nodes and the hand-offs. The results, thus obtained, would be more realistic.

REFERENCES


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