Wireless Networks 8, 325–336, 2002

Wireless Internet Access Using IS-2000 Third Generation System: A Performance and Capacity Study

ZBIGNIEW DZIONG, FAROOQ KHAN, KAMESH MEDEPALLI and SANJIV NANDA *
Performance Analysis Department, Bell Labs, Lucent Technologies, 101 Crawfords Corner Road, Holmdel, NJ 07733, USA

Abstract. The Internet has been growing tremendously in the recent years and applications like web browsing are becoming increasingly popular. In a collective effort to provide seamless access to the Internet, wireless equipment manufacturers and service providers are developing 3G wireless systems that efficiently support current and future Internet applications. In this paper, we evaluate the performance and capacity of a 3G wireless data system based on IS-2000 standard. We consider web browsing as the common application for all users and evaluate the system performance for single and parallel web browsing sessions. We perform this study through a detailed simulation of web traffic model described by distributions of number of objects per page, object size, page request size and page reading time. The simulation includes HTTP and TCP/IP protocols, link level recovery, radio resource management, mobility, channel model and, delays in the Internet and the radio access network. We quantify important system attributes like average page download times and system throughput (Kb/s per carrier per sector). We also evaluate normalized object download time, normalized page download time, penalty in performance due to link errors, link layer buffer sizes needed, channel holding time, average power used and distribution of the power used in the system.

Keywords: wireless Internet, HTTP, TCP, RLP, ARQ, capacity, mobility, multiple users

1. Introduction

The Internet offers a wide range of applications starting from interactive web browsing sessions to speech communications to streaming audio and video applications. Traditionally, access to these applications is obtained through wire-line dial-up or LAN connections. More recently, mobile and wireless access systems are being developed to provide untethered access to the Internet. The low data rates (about 10 Kb/s) provided by the existing second generation (2G) wireless systems used predominantly for voice communications (IS-95, TDMA, GSM etc.) are inadequate to provide these wide range of applications. To this end, an extended effort is underway in the wireless and Internet community in standardizing and developing third generation (3G) wireless systems that can provide higher data rates (up to 2 Mb/s). The collective effort of operators and equipment manufacturers has resulted in the development of several 3G standards: in particular, IS-2000 standard [25], UMTS [12] and EGPRS [13]. Air interface standards for these technologies have been completed and systems based on these standards will be deployed in the next several years. Moreover, enhancements to IS-2000 (1x-EV) and UMTS (HSDPA) standards are already underway to support peak data rates of 2 to 20 Mb/s.

As part of the standardization activity, performance analysis has focussed on characterization of the air interface capacity. Since the air interface capacity of a CDMA network is a function of inter-cell interference, the air interface capacity can only be estimated through multi-cell simulations. Such a multi-cell simulation methodology has been specified in [9]. Performance characterization of the physical link in terms of transmit power, intra- and inter-cell interference, and channel characteristics is obtained from link simulations. The results of the link simulations are used in the multi-cell simulations to obtain system "capacity" results. This methodology has been used to optimize the design of the physical layer. The evolution to 3G is motivated primarily by the emerging data applications. It is expected that web browsing will be the predominant high rate data service over wireless networks. Currently, web browsing contributes more than 70% of the traffic carried over the Internet. The web browsing applications employ the Hypertext Transfer Protocol (HTTP) in order to retrieve the information from web servers. HTTP in turn uses Transmission Control Protocol (TCP) as the transport mechanism for reliable data transferring the web pages. TCP is also used by the Internet file transfer protocol (FTP) for reliable data transfer. The performance of TCP over wireless is well known and is extensively studied in the literature [3,4,7,8,17,18,21]. TCP provides end-to-end recovery and flow control. Link layer recovery protocols in cellular systems operate below the TCP layer and have complex interactions with TCP. The link layer recovery protocol can be optimized for best performance with end-to-end TCP. The tradeoffs are different depending on the size of the end-to-end data transfer. A detailed description of this study is found in [19].

While much of the previous studies of HTTP/TCP over wireless have focused on the protocols themselves, this paper provides a comprehensive study of the cumulative effect of these protocols and the lower layers, in the presence of multiple users. We focus on the 3G-1X system which is IS-2000 system with a single radio carrier of 1.25 MHz. We develop a detailed simulation to capture the perceived performance of the mobile Internet users who are randomly scattered in a cell. When there are multiple users in the system the inter-

* Now with Narad Networks, 515 Groton Road, Westford, MA, USA.