Wireless IP - a new PCC Project

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1 BACKGROUND

We believe that virtually all traffic will soon be packet based using IP. Traffic to small end-user devices, often mobile, is expected to be the most explosive market of all. The use of these devices is expected to grow at an even higher rate than the present Internet traffic. We are on the verge of the "post PC era", and the PCC research program is well positioned with respect to this trend.

So what are the problems? One of them is the marriage between IP and wireless networks with fading channels. IP is designed for fixed networks of high quality (low bit error rate) and a large available bandwidth. Unfortunately, the quality of wireless networks for mobile users is often severely degraded due to fading and interference. Moreover, they are severely bandwidth limited[1]. Therefore IP, as we know it today, does not work properly.

Powerful channel coding can alleviate bad quality (high bit error rate), and it is frequently mentioned as a straightforward solution to improve IP traffic over wireless links. In our opinion, this is an inefficient solution, since it leads to unnecessarily low spectrum efficiency. The main reason is that mobile wireless links are time varying in nature. Traditional coding would therefore be excessively conservative since it is designed for the worst case channel (deep fades). To maintain high quality transmission, we instead advocate the use of *adaptive techniques* so that the channel can always be used to its maximum. Such techniques may be blind in situations where the channel is not known at the transmitter[2].

Another problem with IP in general, and IPv6 in particular, is the extensive overhead. This is not an essential problem on fiber links, since bandwidth is not limited to the same extent as it is on a wireless link. Using today's IP on a wireless link will significantly reduce the spectral efficiency (defined as user data rate per one Hz of bandwidth) due to the overhead. Header compression techniques are available, but the current proposals do not make much of a difference on a wireless link. The fraction of the available capacity used for headers will have to be reduced considerably.

A further issue is the well known fact that TCP/IP cannot offer a given maximum delay. This is a problem on both fixed and wireless links, but it becomes a worse problem on fading wireless links due to the time-varying nature of the channel. This problem has been considered in the literature, but it is still far from solved. The problem is also closely connected to multiple access resource scheduling. Therefore protocols and scheduling algorithms would benefit from being designed jointly.

2 PROJECT OBJECTIVES

The objective of this project will be to find and analyze new and improved air interface techniques and protocols for packet based traffic over wireless and mobile data links[3].

The ideas and concepts we propose are interconnected and mutually supporting. The aim of the project as a whole is that the research results are to be integrated into a system-level proposal.

Our project is intended towards optimizing both quality of service and system throughput; whatever the type of data or source coding, and whatever the quality and variability of the underlying wireless link, our task is to provide more efficient packet transmission.

3 ELEMENTS OF A SOLUTION

We believe that Internet traffic on the fixed network should *not* continue over fading wireless links as TCP/IP traffic; it

[1] The available capacity will, of course, increase when GPRS, EDGE and 3G mobile systems are introduced, but the capacity of fixed broadband connections will expand even more. Thus, in relative terms, the frustration encountered by mobile users of wireless links will probably increase rather than diminish.

[2] The only available information about the channel condition is in that case the ACKs and NACKs received from the recipient.

[3] Note that we focus on a more difficult situation than that encountered in *fixed* wireless links, such as WLANs. Our objectives also differ from "mobile IP", where worldwide mobility of IP addresses is the goal.

should only appear to far-end users and to some of the mobile users as if this was the case. To optimize throughput and/or user satisfaction over the wireless links, we intend to combine the following tools and concepts into a radio access scheme for packet data:

- *Gateways and proxies.* At the interface between the fixed network and the wireless links, there should be gateways, or low-level proxies. They communicate with maximum speed over fiber with far-end users while optimizing and scheduling the traffic to wireless users. They buffer the data, reformat the data and adapt the protocols to the quality of the wireless link and to the type of wireless client. We will propose solutions that are partly different for "thin clients" (WAP mobile phones, not-so-intelligent appliances,..) and "fat clients" (future devices with or above present laptop-like power).

- *Link adaptation.* Each wireless link will vary in quality, and different users will have different requirements for speed and latency. In some situations, the channel quality may be known at the transmitter and then this information should be utilized in a non-blind technique. Such information will improve the throughput considerably. We intend to build on our present work in this area, on adaptive modulation and coding and on hybrid ARQ schemes [1],[2]. We will use and further develop methods based on the prediction of channel quality (C/I), which have been developed within another project [3]. Such predictions are key tools in any non-blind adaptation of the transmission over the channel.

- *System-level adaptation and scheduling.* With many users in a packet-oriented system, multiple access resource scheduling of the users becomes a key issue, since different users (or links) will interfere with one another. The objective is to obtain high system level performance, in addition to an adequate performance for each user.

  Within the Radio Interface Design project, we have investigated the effect of adaptive modulation, along with time-slot scheduling of IP-like traffic in a scenario involving several types of mobile hosts and one base station. Our recently developed scheduler keeps the bit error rate at attractive low, pre-specified levels, well suited for Forward Error Correction (FEC) codes [4]. Moreover, the scheduler splits the bandwidth according to the traffic situation, so that either system throughput or user satisfaction is optimized[4].

  Multivariable feedback algorithms for transmitter power control will be important in our continued investigation of system-level optimization. They will also be important for limiting the power consumption of mobile terminals.

  Much work remains to be done on these topics. Obviously, the quality plays an important role. It is not always clear which quality measures that are important: For some users, high quality may be to transmit at a low data rate with low bit error rate, whereas for others quality may be a high data rate with a low delay, or even isochronous transmission. Requirements for related military wireless mobile data systems, see e.g. [5], are partly different from those in our intended civilian focus.

- *Efficient protocols for wireless links.* We will propose new more efficient protocols for the wireless links, with less overhead and with packet sizes optimized for this particular mode of transmission. The goal is to design them so that they are fully transparent to the application. Some clients (such as programs in laptops) will believe they are communicating over an end-to-end TCP/IP link. For that reason, sufficient information will have to be transmitted over the wireless link so that an IP stream can be re-created at the wireless terminal.

The concepts above are interrelated and rich opportunities exist for creating a whole that is more than the sum of these parts. We have taken this as our task during the next two years.

[4] Here, user satisfaction means that the requirements of different users with differing requirements such as priority, time delays and bit-rates are satisfied as much as possible.

REFERENCES

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[2] S. Falahati and N. C. Ericsson, "Hybrid type-II ARQ/AMS supported by Channel Predictive Scheduling in a Multi-User Scenario" Submitted to the IEEE Vehicular Technology Conference - VTC'2000, Tokyo, May 2000.

[3] T. Ekman, G. Kubin, M. Sternad and A. Ahlén "Quadratic and Linear Filters for Mobile Radio Channel Prediction", IEEE Vehicular Technology Conference - VTC'99-Fall Amsterdam, The Netherlands, September 19-22 1999.

[4] N. C. Ericsson, "Adaptive Modulation and Scheduling of IP-traffic over Fading Channels", IEEE Vehicular Technology Conference - VTC'99-Fall Amsterdam, The Netherlands, September 19-22 1999. See also contribution at present PCC workshop.

[5] DARPA project GloMo, Global Mobile Information System
http://www.darpa.mil/ito/research/glomo/index.html