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Multiservice traffic performance in mobile networks

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Analysis of traffic performance implies capturing the three-way relation between capacity, demand and performance. This relation is generally probabilistic expressing performance criteria like blocking probabilities or expected response times in terms of assumed statistical traffic characteristics. As well as being a requirement for cost effective sizing, a sound understanding of this relation is essential in designing network traffic controls and resource sharing schemes. In this talk we discuss the nature of the traffic performance relationship in multiservice wireless networks such as GPRS and UMTS.

A significant complication in analysing the traffic performance of wireless networks is that their capacity cannot be expressed simply, like link bandwidth in a wireline network, and is essentially different in forward and reverse paths. The uplink is most constraining for symmetric communications. Its capacity is interference limited with each mobile consuming a certain amount of resource in its own and in neighbouring cells. For data services, the downlink is generally the most heavily loaded. Its capacity is limited by available base station power as well as the impact of inter-cell interference.

Demand in a multiservice network can be classed in two broad categories that we call “streaming” and “elastic”. Streaming traffic includes both real time conversational traffic and downloaded audio and video sequences and is characterized by a requirement on the network to preserve the transmitted signal (low loss and bounded delay). Elastic traffic, on the other hand, corresponds to the transfer of all forms of digital document (files, Web pages, MP3,...) and is called elastic because the transmission rate can be freely adjusted depending on network load. Quality of service requirements for elastic traffic are typically expressed in terms of response times.

The essential traffic characteristic of a streaming flow is its (generally variable) bit rate while an elastic flow is characterized more simply in terms of its size. In a wireless network these characteristics are not sufficient to determine resource requirements. It

is additionally necessary to specify a spatial component determining the amount of resources consumed by a mobile in its own and in neighbouring cells. In analysing the uplink, it has been suggested (e.g., by Evans and Everitt) that this consumption can be conveniently as a vector of “effective bandwidths”. The downlink power requirement to transmit a given document clearly also depends on the position of the mobile receiver and the transmission quality of its paths to the transmitters.

A significant issue in designing or operating a multiservice network is the definition of service classes and the way resources are shared between their respective flows. For instance, the 3GPP standards for UMTS envisage four service classes: conversational and streaming, interactive and background. In our studies of wireline networks we have concluded that further division beyond streaming and elastic, as discussed above, is neither feasible nor useful. We will discuss the reasons for this (so far unpopular) point of view and examine to what extent they apply in wireless networks. The essential distinction between streaming and elastic traffic is that the former requires open loop control while the latter is most efficiently handled under closed loop control.

Under open loop control, the network applies admission control to ensure that sufficient resources are available to handle admitted streaming flows with adequate quality of service. “Bufferless multiplexing” emerges as the most satisfactory form of statistical multiplexing, facilitating control and providing excellent performance. Unfortunately, this kind of resource sharing is inefficient when the resource requirement of individual flows is not small compared to system capacity, as may indeed occur with GPRS and UMTS. To allow significant queuing delays (buffered multiplexing) improves efficiency somewhat but at the expense of traffic performance that depends significantly on source characteristics. The definition of a satisfactory admission control strategy for open loop controlled traffic in a wireless network remains an extremely important open problem. Experience in wire-

line networks suggests the only satisfactory solution is measurement-based. To rely similarly on measurements in wireless is natural but it is unclear how one can simply integrate the rate and spatial characteristics of ongoing and newly arriving flows.

Data traffic is amenable to closed loop control since it is elastic. In wireline networks, approximately fair bandwidth sharing is realized by TCP and can be enforced by scheduling. Fair sharing leads to a particularly simple traffic performance relation since it exploits the well known insensitivity properties of the underlying processor sharing queue discipline. In a wireless network, it is more appropriate to fairly share base station power than bandwidth. Borst has recently shown how the processor sharing model again applies in this case. He is thus able to robustly express the capacity of an isolated cell under proportional fair power sharing as defined by Tse. It appears considerably more complex to extend these results to a multi-cell framework.

The integration of streaming and elastic traffic occurs synergistically in wireline networks. The same mutual advantages of increased efficiency and simplified control should accrue in a wireless network. However, to the author's knowledge the issues of designing an appropriate resource sharing scheme and the analysis of its traffic performance relation remain largely open.

Analysing the traffic performance relation requires both a solid knowledge of the physical constraints of the radio network environment and an appreciation of the statistical nature of traffic and the fundamental resource sharing trade-offs. This combination remains rare and we are acutely aware of our own deficiencies in understanding wireless technology. We hope, however, that our experience in analysing the performance of multiservice wireline networks will help in identifying important open issues and at least pointing to the nature of sought-for solutions.

Jim Roberts has a BSc in mathematics from the University of Surrey, UK and a PhD from the University of Paris. He has been with the France Telecom research labs since 1978. His research has been mainly in the field of performance evaluation and design of traffic controls for multiservice networks. He was chairman of three successive European COST projects on the performance of multiservice networks, this activity culminating in the publication of the book "Broadband Network Teletraffic" (Springer 1996).

He has published quite extensively and is or has been a member of several journal editorial boards including Computer Networks and IEEE/ACM Transactions on Networking. He was co-recipient of the best paper award for Infocom 99. He was a guest editor for the IEEE JSAC issue on Internet QoS in 2000. He is member of many conference programme committees in the networking field including Infocom and SIGCOMM. He is TPC co-chair for Infocom