Research Report 2000

Signal Processing

Sub-Project 1:
Effect of physical layer signal processing on Quality of Service

The aim of this sub-project is to study the effect of physical layer signal processing on network throughput.

Preliminary work, in collaboration with Vincent Poor, has begun. At this stage our goal is to analyse, in a system-theoretic sense, the performance of a simplified feedback system. An adaptive linear multiuser detector in the downlink demodulates the received signal. The signal to interference ratio (SIR) is computed as a function of the linear multiuser detector weight vector. This SIR in turn affects the admission control algorithm and power control algorithms of the wireless network. The entire system can be modelled as a dynamical feedback system. We are currently examining issues such as stability, short-term (transient) and long-term dynamics.

Sub-Project 2:
Adaptive Interference Suppression and Spatial Diversity.

The aim of this sub-project is to develop state-of-the-art signal processing algorithms for interference suppression in both wireless and wireline communication systems.

Demodulating a given user in a DS/CDMA wireless network requires processing of the received signal to minimize wide-band multiple access interference (MAI) caused by other spread-spectrum users in the channel. Adaptive filtering algorithms are widely used to implement linear multiuser detectors. By exploiting powerful results in the weak convergence theory of stochastic approximation algorithms, we have derived fast converging robust linear multiuser detection algorithms.

In collaboration with George Yin of Wayne State University, we have developed multiuser detection algorithms that dynamically adjust the step size in an optimal manner. The methods provide a significant performance improvement over fixed-step size adaptive linear multiuser detectors especially in a dynamic environment where users rapidly appear and leave.

In 1990, the Russian mathematician B.T. Polyak invented iterate averaging which results in the Least Mean Squares (LMS) algorithm having a convergence rate identical to the recursive least square (RLS) algorithm -- yet with an order of magnitude lower computational cost. We have used these results to develop asymptotically efficient blind multiuser detection algorithms. Our performance analysis of the resulting algorithm shows that the mean square error of the algorithm is independent of the eigen-distribution of the received data -- making the algorithms extremely robust to rapidly fading channels.

We have analysed reduced complexity adaptive multiuser detection algorithms such as the sign error and sign regressor algorithms, and we have shown that the convergence of these algorithms can be accelerated by iterate averaging. Asymptotic expressions for the signal to interference ratio of these algorithms have been derived.

Another area of activity has been the development of subspace based algorithms for blind channel identification and equalization. In the future, we intend to use the adaptive step size algorithms developed in sub-project 1 as detailed above for channel equalization algorithms such as the CMA (constant modulus algorithm). This work will be a collaboration with C.R. Johnson of Cornell University who is scheduled to visit CUBIN in 2001.

Optical Networking

The first major activity in this project is to develop a model of an Australian national network that can carry the projected traffic demands of the next decade using the new generation of optical transport technology. At present, we are concentrating on the architecture of metropolitan and national trunk networks, rather than access network design. In order to formulate the problem, we have defined three future scenarios for customer demand in terms of 10 Mb/s, 100 Mb/s and 1 Gb/s connections to the home. In addition, we have specified the capacity of the WDM equipment that we expect to be available, e.g., up to 40 Gb/s per wavelength, up to 250 wavelengths per fibre, and optical cross-connect units with up to 1000 ports.

We have defined several alternative network architectures that can be applied to each demand scenario. We have applied these architectures to a simple network of three cities representing Sydney, Melbourne and Canberra. These initial designs have provided an insight into the major network bottlenecks, such as backbone routers, and optical cross-connect units. For example, we found that a linear increase in the number of ports/cross-connect can produce a quadratic reduction in the number of interconnecting fibres for a fully meshed network.

Our next step is to develop a design tool for optical layer network optimisation, based on these prototype architectures. This tool will help us to investigate differences between the optimal architecture for each demand scenario, and an evolutionary upgrade path for the trunk network.

An associated research activity in this project focuses on decentralized dynamic routing algorithms for use in multi-fibre networks with optical switches and with electrical switches at the access points. We have simulated a wide range of networks and analysed the utilization, the effect of wavelength converters, the effect of reallocation of traffic, and the effect of using alternative paths on utilization. The results of our simulations demonstrate that the effect of wavelength converters is small but non-negligible in the case of dynamic routing of asymmetrical non-uniform traffic. Although alternative routes in the network are necessary for protection, we have shown that linking alternative routes in conjunction with the dynamic routing algorithm increases the utilization of the network.

Performance Assurance

Sub-Project 1:
Network design

The aims of this sub-project are to:

- Develop criteria for topology design taking performance into consideration
- Investigate topology optimisation techniques for wireless and wireline networks.

In collaboration with the Modelling Ultra-Broadband Networks project, we are investigating the effect of aggregating traffic from access networks (fibre, cable, copper and wireless) on the core network, how best to employ flow control, and other network controls, in the presence of bottlenecks. The assumption here is an IP over WDM core network, with label switching at the network layer, and lambda switching at the physical layer.

New criteria for WDM network design have been developed. The aim here is to design flexible networks that can cope not only with homogeneous traffic growth but also with significant traffic shifts. This is part of the general problem of finding efficient algorithms for designing future networks which are optimal in terms of some measure such as the present value. New insights into the computational complexity of this problem have been developed.

We have developed a model for optimal assignment of base stations in a CDMA network. This work provides an explicit formula to obtain the distance between base stations, assuming uniform traffic, to meet the quality of service constraints. Work is in progress to extend to nonuniform traffic, and for applications in 3G networks.

Sub-Project 2:
Traffic Management

The aims of this sub-project are to:

- Develop efficient techniques for traffic management, Connection Admission Control (CAC), scheduling and congestion control.
- Develop means for modelling and performance evaluation of traffic management.

We have developed a new measurement based CAC scheme and a framework for comparison between different alternatives. This answers the fundamental question of what needs to be measured and how best to use it. Additional issues when extending CAC to multimedia, wireless environmenthave also been examined.

We have developed a model based CAC which relies on effective bandwidth techniques for the special traffic conditions of CDMA networks. In particular, spatial Poisson process models are used to capture bursty traffic on the uplink of 3G CDMA networks.

New techniques to calculate outage possibilities in wireless networks have been developed. Previous techniques in the literature are not accurate in the realistic scenario in which large-scale fading is "heavy tailed". Our techniques are extremely accurate, and will be used in future research to design CAC algorithms for future networks

A newly developed unified duality model for Transport Control Protocol (TCP) congestion controls interprets the current protocols as carrying out a distributed computation over the Internet to maximize aggregate user utility. It enables a rigorous study of stability, optimality, and fairness properties of these protocols, exposes their weaknesses, and leads to enhancements. Based on this model, a new active queue management scheme has been invented that achieves high network utilization while maintaining negligible loss and delay.

We are working on schemes aiming to cope with unfriendly traffic streams (those who do not adapt their rate during congestion) by packet discarding.

Active Networks

Sub-Project 1:
Active Networks for QoS

The aim of this sub-project is to study fundamental issues related to active networks and their influence on Quality of Service.

We are studying programmable routers, and how these can be used to provide enhanced QoS in networks. The ability to process packets more intelligently assumes that there is adequate processing capacity in the routers. This is more likely in access routers, where the level of traffic is low, than in backbone routers. Consequently, we are concentrating on using active networks to improve QoS in limited bandwidth access networks. An important example of such an environment is streaming delay sensitive applications over bursty, wireless channels. In this context, active networking can be used to feed back information about congestion, so that the source can selectively drop packets or adapt its coding scheme.

Sub-Project 2: Active Networks for Distributed Network Monitoring

The aim of this sub-project is to use active networks in the monitoring of network performance.

An important issue in network management is how to detect and diagnose network performance problems. At present, each router collects a range of performance measurements that need to be downloaded to a centralised management site for analysis. This centralised approach can become a bottleneck when monitoring a large network. An alternative approach is to use active networking for distributed monitoring. In this case, each router can selectively activate monitoring in response to a problem, and cooperate with neighbouring routers to isolate the cause of the problem.

We have identified two applications where active monitoring can be used: network intrusion detection, and the diagnosis of congestion problems. The research challenge for active networks, in this context, is to define the functionality and intelligence that needs to be available in routers, e.g., detecting abnormal traffic patterns, and correlating patterns of behaviour between routers. Currently, we are developing suitable monitoring algorithms that can be used by active networks for intrusion detection.

Sub-Project 3: Caching Strategies

The aim of this sub-project is to use active networks to minimise network latency using caching techniques.

As a first step, we have implemented two web caching schemes, Internet Cache Protocol (ICP) and Cache Array Routing protocol (CARP) to study their effectiveness in improving web access. We have also developed a simulator to study these schemes under different access patterns. The results indicate that CARP is a better scheme, as it improves storage utilisation and balances the load among many web servers.