An Optimal Call Admission and Bandwidth Reservation Scheme for Future Wireless Networks

*Mehhoob Alam, Wael Badawy and Graham Jullien**
Department of Electrical and Computer Engineering
**ATIPS Laboratory*
University of Calgary, Canada
{alam, badawy}@enel.ucalgary.ca, jullien@atips.ca

Abstract

The next generation wireless networks promises availability of a wide variety of services. To be supported successfully, it is necessary to provide quality of service (QoS) between end-systems with the resources whose cost is discouragingly high. This paper proposes a new scheme for call admission and bandwidth reservation for the next generation wireless networks. The proposed scheme OPBR (optimal cell partition based bandwidth reservation) does an optimal partitioning of the cell to give high degree of call admission and successful handoff. In addition it offers effective bandwidth utilization and guarantee QoS. The performance of the scheme is done by analytical modeling and simulation experiments. A comparison with two different schemes (PBR and adaptive reservation) shows desirable results can be achieved by proposed scheme with better performance for various QoS parameters.

Keywords: Bandwidth reservation, Call admission control, Quality of service, Wireless networks and Multimedia networks.

1 Introduction

The next generation wireless network will support a wide variety of services. The cost of providing these services is discouragingly high in terms of required resources. Extremely efficient resource management is required to provide these services at the affordable cost. With over one billion mobile users estimated by the end of 2002 [1], with packet based multimedia services, the establishment of connection is crucial for quality of service (QoS) provisioning between the end-systems. The current trends are towards shrinking all size in order to accommodate more users. This result in frequent handoff due to user mobility, thereby making QoS provisioning a more intricate question.

In wireless communication the coverage area is divided in to cells, with each cell covered by a base station. The mobile user moves from one cell to another cell, a handoff take place from one base station (BS) to the other. Current research offers solution to this rapid handoff, which can be classified in to two broad categories. The first method is based on hierarchical network architecture. In this resources are reserved in neighboring cell in advance based on location of the mobile and call admission. Second broad category is based on probabilistic model and predicts future resources depending upon past history. The second approach had the disadvantage of not guaranteeing QoS, however sudden degree of confidence can be achieved which is necessary but not sufficient to support rapid handoff for the real time traffic.

The main contribution of our work is to provide QoS guaranteed while optimizing the bandwidth utilization and increasing probability of call admission. The analytical and simulation result has shown effective utilization of the bandwidth with increase probability of handoff and call admission. The scheme is based on optimal partitioning of cell to achieve better performance for various QoS parameters.

The paper is organized in six sections. In next section, related work in the literature is reviewed. In section three, proposed scheme is discussed. Analytical model and simulation results are quoted in section four and five respectively. Finally paper is concluded in section six.

2 Previous Work

Many schemes have been proposed in the literature [2,3,4], which guarantees QoS. In [2] admission control is based on pre-determined threshold value of either the mean delay or the packet loss probability of data traffic. This scheme however does not reserve bandwidth in the neighboring cell to respond to rapid changes in network statistics. In [3] resources are allocated based on different classes of traffic but does not consider bandwidth reservation in advance. In [4] admission is based on dynamic channel assignment. The network traffic is first evaluated, which forms the bases of channel assignment to new calls, however it doesn’t reserve the bandwidth in the neighboring cell.

Recently some popular work is reported [5, 6, 7] which in addition to call admission reserve sufficient resources in the neighboring cells to guarantee QoS. In [5] a bandwidth compaction and call admission framework is proposed which improves the call admission probability. Increased reservations in this case give rise to lower value of bandwidth utilization, which is quite precious. In [6] QoS is guaranteed by accepting a new call when required bandwidth is available in the local and immediate neighboring cells. The probability of going in a neighboring cell (1/6 in this case) is far away from practical for reserving the bandwidth, thereby reducing the call admission rate and lower values of bandwidth utilization. In [7] a partitioned cell based bandwidth reservation scheme is proposed in which each cell is partitioned in to six sectors or sub cells and bandwidth is reserved in the immediate neighboring cell only. The scheme is quite practical however as the admission is based on the availability of bandwidth resources in the local and one of the neighboring cell, the resulting call admission rates quoted are quite lower.

Our proposed scheme is compared with two most popular schemes [6, 7] and result shows that proposed scheme is most desirable and achieves good performance with less bandwidth resource.

3 Proposed Optimal Cell Partition Based Bandwidth Reservation [OPBR] Scheme

The support for bandwidth-intensive (multimedia) services in mobile cellular networks introduces the problem of frequent handoffs and makes resource allocation difficult. The paper considers an infrastructure based-wireless network as shown in Figure 1.

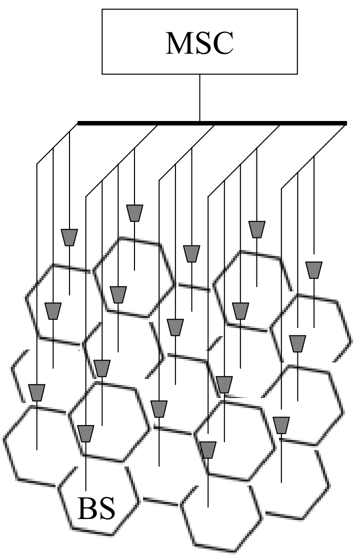

Figure 1 Wireless Network Infrastructure

A mobile can originate and terminate multiple data connections that enable it to communicate with other communication devices. All communication to and from the mobile is through the BS. The proposed OPBR scheme assumes that each cell is partitioned in to six sectors or sub-cells as shown in Figure 2. It is possible to sectorize each cell by using the directional antenna and mobile location can be determined from the antenna from which the signal is received.

A departing region is defined on the out skirts of the cell as shown by marked region in Figure 2. The remaining region is defined as local. The mobile users in the cell can be classified as departing or local depending on its location. This is established either via the use of sectorized antennas or by taking RSS measurements at the six neighboring BS. These techniques can at time lead to severe inaccuracies due to various radio propagation conditions. A scheme based on combination of above with knowledge of terrain condition to predict user location will perform better.

3.1 Bandwidth Reservation.

The bandwidth reservation scheme OPBR is based on optimal portioning of cells. The portioned sectors have optimal number of neighbors to give better bandwidth utilization, call admission and successful handoff. The possible mobility of the MS (Mobile station) to neighboring cell in our case is as shown in Figure 3.

In our scheme the bandwidth reservation is based on following two criteria.

- The type of traffic (real / non-real time).
- Location of the MS (local / departing)

The bandwidth is reserved for the real time caller originating call in the departing region or while moving from local to departing region only. The framework of call reservation is based on nearest and immediate nearest neighbors. Due to optimal sectoring of the cell a MS “A” has two nearest neighbors (e.g. N1 & N2 in Figure 4) and two immediate nearest neighbors (IN1 & IN2 in Figure 3). It is important to note that any error in MS location prediction is quite tolerable due to optimal sectoring of the

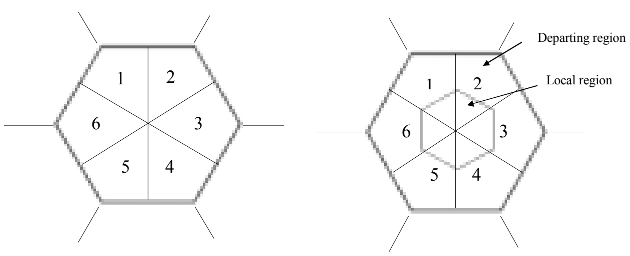

Figure 2 Optimal partitioning of cell

cell. When a real time call is originated in the departing region, in addition to the availability of bandwidth at the originating cell, equivalent amount of bandwidth is reserved in the nearest neighbors (N1 & N2). If the bandwidth is not available in any of the neighbor cell (say N1) then it is borrowed form one of the immediate nearest neighboring cells (either $IN1_{N1}$ or $1N2_{N1}$ in this case).

For a user moving from local area to departing area the bandwidth is reserved in the same manner as discussed above. In order to guarantee QoS the boundary of local and departing region is kept as a function of user mobility and it is up to vendor to decide its threshold.

A high mobility system with reduced cell size will observe frequent handoff, forcing local area to be as small as possible to offer 100% QoS. The situation will permit admission of calls only when bandwidth is available in home and predicted neighboring cells. However depending upon the traffic behavior appropriate threshold / boundary for the local and departing region be selected to give better efficiency and utilization of the bandwidth.

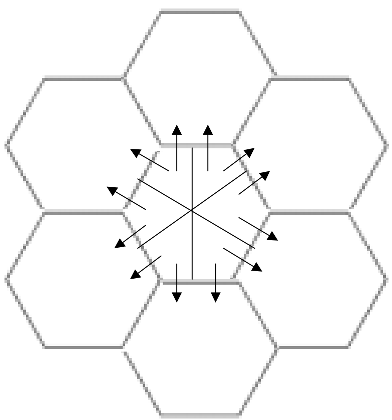

Figure 3 Possible movement of mobile from sub-cell to neighboring cells.

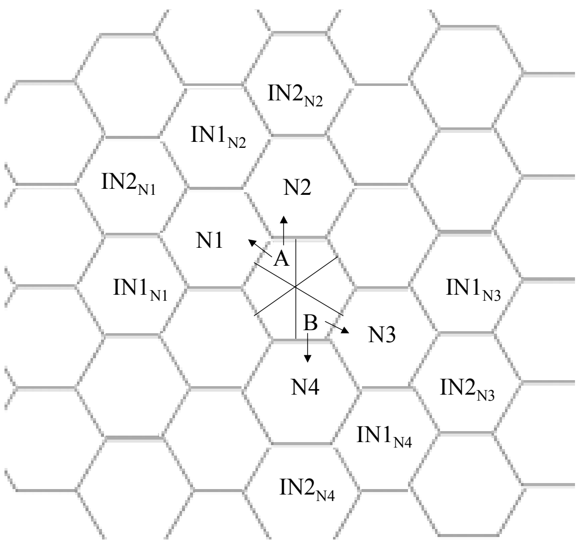

Figure 4 Nearest neighbor and immediate neighbor for bandwidth reservation / possible borrowing.

3.2 Call Admission and Control

Our new call admission algorithm is presented as a flow chart in Figure 5. In case of new call the request is accessed based on real time or non-real-time and availability of bandwidth in the originating cell. The call admission criteria are difficult for both type of application. As discussed before the real time user is classified to be in local or in departing region. If the user is in departing region the bandwidth is reserved based on predicted destination cells. If the reservation as discussed in previous subsection is successful the call is admitted else it is rejected. For the non-real time user the admission is primarily based on the bandwidth in the local cell and space in the buffer of non real-time packet queue.

4 Analytical Model and Analysis

In this section we evaluate expression for call admission and successful handoff and bandwidth utilization for the proposed scheme. A comparison with earlier two popular schemes [6,7] is also done. In this analytical model we will mainly focus on real-time users.

4.1 Call Admission & Successful Handoff

Parameter proposed in [5] is used for analytical analysis of call admission and successful handoff. The assumptions taken for analysis are as follows.

- User changes cell at least once during the session.
- On the average same amount of bandwidth is required for all calls.
- Unavailability of bandwidth is the only reason for handoff failure.

Let P_{BW} be probability that sufficient bandwidth is

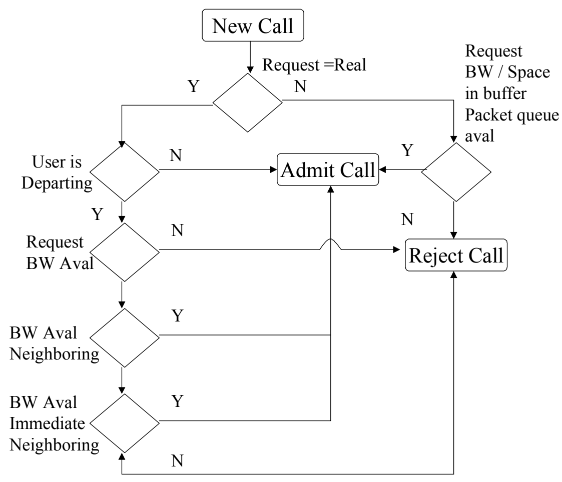

Figure 5 Flow chart of call admission control

available in any cell to admit a call and Let A and H be the event denoting call admission and successful handoff respectively.

We will derive an expression of P(AH) (probability of call admission and successful handoff) for the proposed technique and will compare it with two other techniques.

OPBR (Proposed Scheme)

The probability of call admission and successful handoff is given by

$$P(AH) = P(A)P(H|A) \text{ -------- (1)}$$

Where P(A) is the probability of call admission and P(H|A) is the probability of handoff given the call is admitted. P(H|A) is given by

$$P(H|A)=P^2_{BW}+2P_{BW}(1-P_{BW})(2P_{BW})+(1-P_{BW})^2(2P_{BW})^2$$

$$P(H|A)=P^2_{BW}[1+2(1-P_{BW})]^2 \text{ ---------(2)}$$

For the local region the probability of call admission is P(A)= PBW , hence using equation 1 the P(AH) is given by

$$P(AH)= P^3_{BW}[1+2(1-P_{BW})]^2 \text{ ---------(3)}$$

Adaptive Reservation

The algorithm [6] admits a real time call only when sufficient bandwidth is available in the originating as well as in the neighboring six cells. The P(H|A) is given by P(H|A)=1 with call admission probability P(A) = P7BW, hence the overall probability of call admission and successful handoff is given by

$$P(AH)= P^7_{BW} \text{ ---------(4)}$$

PBR (Partition based bandwidth reservation)

In partition based reservation [3] the call is admitted when sufficient bandwidth is available in the originating as well in one of the neighboring cell. The probability of call admission and successful handoff can be derived as follows.

$P(A)=P_{BW}$ and $P(H|A)=P_{BW}$

Where as $P(AH) = P^2_{BW}$ ----------(5)

Comparison

A comparison parameter (τ) is defined as ratio of proposed scheme probability of call admission and successful handoff with the probability of other scheme. τ is given by

$$\tau_{other\_scheme} = \frac{P(AH)_{proposed\_scheme}}{P(AH)_{other\_scheme}} \text{ -------- (6)}$$

The value of τ for the adaptive reservation is given as follows

$$\tau_{adaptive\_scheme} = \frac{P(AH)_{proposed\_scheme}}{P(AH)_{adaptive\_scheme}}$$

$$\tau_{adaptive\_scheme} = \frac{P^3_{BW}[1+2(1-P_{BW})]^2}{P^7_{BW}}$$

$$\tau_{adaptive\_scheme} = \frac{[1+2(1-P_{BW})]^2}{P^4_{BW}} \text{ ------ (7)}$$

The value of τ for the PBR is given as follows

$$\tau_{PBR\_scheme} = \frac{P(AH)_{proposed\_scheme}}{P(AH)_{PBR}}$$

$$\tau_{PBR\_scheme} = \frac{P^2_{BW}[1+2(1-P_{BW})]^2}{P^2_{BW}}$$

$$\tau_{PBR\_scheme} = [1+2(1-P_{BW})]^2 \text{ ------ (8)}$$

The value of the PBW (probability that sufficient bandwidth is available in the cell for call admission) ranges forms $0\leq P_{BW}\leq 1$. A plot of the comparison factor for various schemes is plotted against all possible values of P_{BW} . Figure 6 shows a comparison of proposed scheme with two other schemes. The plot shows that the proposed scheme has got higher values of call admission and successful hand off rate. The only scheme, which has close result to proposed scheme, is PBR In which it has higher values for $P_{BW}\leq$ 0.14 but for all practical cases the probability of availability of bandwidth for a call admission in any cell is always greater then 0.14.

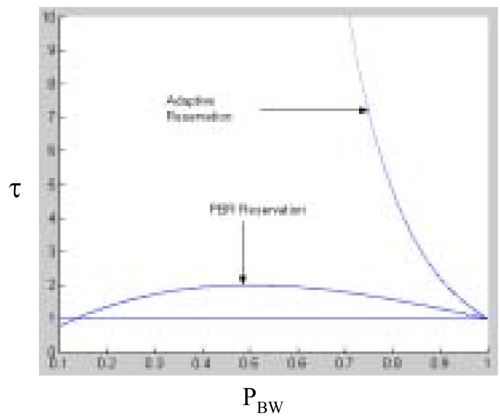

Figure 6 Comparison parameter τ plotted as function of P_{BW}

4.2 Bandwidth Utilization

Resource reservation schemes reserve bandwidth in the adjacent cells to provide better performance and guarantee QoS. Bandwidth is a precious resource and its effective utilization is a key indicator to determine the suitability of any technique. In [7] K.K Pati defines a metric that can be used to determine the effective bandwidth utilization and is as follows

$$Be_{ff} = \frac{\sum_i \sum_j B_{j,i}}{\sum_i \sum_j B_{j,i} + \sum_k \sum_l \sum_m B_{m,l,k}} \times 100 \text{ ----(9)}$$

Where Beff is the percentage of bandwidth being effectively utilized, $B_{j,i}$ is the bandwidth used by mobile host i in cell i, $\sum_j$ the summation to evaluate BW used by all mobile user in cell i, the $\sum_i$ summation to find out the total BW allocated to all the active mobile users in all the cells. $B_{m,l,k}$ is the BW reserved in cell k by the mobile host k present in the neighbor cell l to cell k, $\sum_m$ the summation to get the bandwidth reserved in cell k by all mobile users in neighbor cell i, $\sum_i$ the summation to evaluate the bandwidth reserved by all mobile users present in all neighbor cell k and $\sum_k$ is the summation to get the bandwidth reserved in all cells. To study the effective bandwidth utilization by the proposed and reference schemes, we will derive the expression for the Beff. Let m be the total number of mobile users at any time and f be the bandwidth used by any user when the call is admitted. With this basic assumption we will derive the expression of the effective bandwidth utilization.

For the adaptive reservation [6] call admission is possible only after allocating the required bandwidth in originating as well as all the neighboring cells, the value of Beff is given by

$$\sum_i \sum_j B_{j,i} = mf \text{ and } \sum_k \sum_l \sum_m B_{m,l,k} = 6mf$$

$$Be_{ff} = \frac{mf}{mf + 6mf} = \frac{1}{7} = 14.28\% \text{ ------- } (10)$$

In PBR [7] the call admission is based on allocating the bandwidth in originating as well as in one of the neighboring cell, hence the value of the Beff is given as

$$\sum_i \sum_j B_{j,i} = mf \text{ and } \sum_k \sum_l \sum_m B_{m,l,k} = mf$$

$$Be_{ff} = \frac{mf}{mf + mf} = \frac{1}{2} = 50\% \text{ ---------}(11)$$

OPBR(proposed) scheme assumed the bandwidth to be reserved in originating as well as in the two predicted cells. The basic assumption is, “departing area = total cell area” (i.e the bandwidth is need to be reserved for all the users). The values of the Beff is given by

$$\sum_i \sum_j B_{j,i} = mf \ \& \ \sum_k \sum_l \sum_m B_{m,l,k} = 2mf$$

$$Be_{ff} = \frac{mf}{mf + 2mf} = \frac{1}{3} = 33.33\% \text{ ------- } (12)$$

If the departing area is assumed to be less than area of the cell, the Beff will increase with increase in ratio of the local area to the cell area. Let x be define as ratio of the local area to the cell area. Then the modified Beff (Beff(modified)) is given by.

$$B_{eff}(\text{modified}) = \frac{2}{3}x + \left(\frac{mf}{mf + 2mf}\right) = \frac{2}{3}x + \frac{1}{3} \text{ --------}(13)$$

$$\text{Where } x = \frac{local\_area}{cell\_area}$$

A plot of the equation (10-13) is given in Figure 7. Equation 16 is plotted against values of x shows that for a value if x≥0.25 the proposed scheme out perform the other two schemes for the bandwidth utilization.

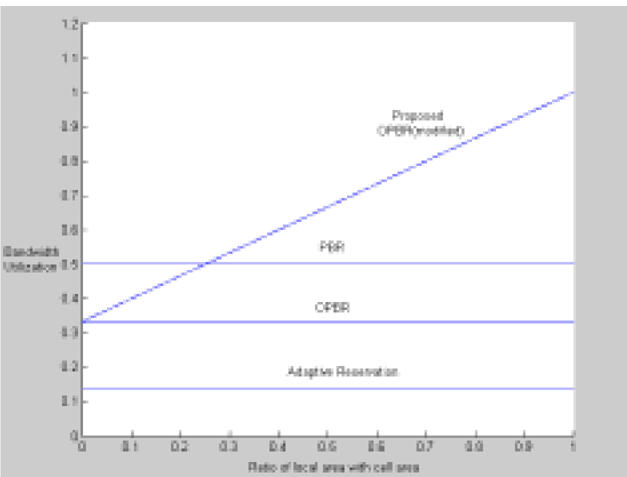

Figure 7 Bndwidth utilization as percentage of the reserved bandwidth.

5 Simulation Model

To simulate various reservation schemes for the total amount of bandwidth required, we assume following.

- Poisson call arrival and handoff time distribution.
- Exponential call holding time distribution.
- 15% probability of high bandwidth (384kb/s) calls handed off each minute.
- 85% calls randomly distributed between 16 and 56 kb/s.
- Assumption is based on network support to 16kb/s voice service, 16 to 56 kb/s Internet and 384 kb/s of real time

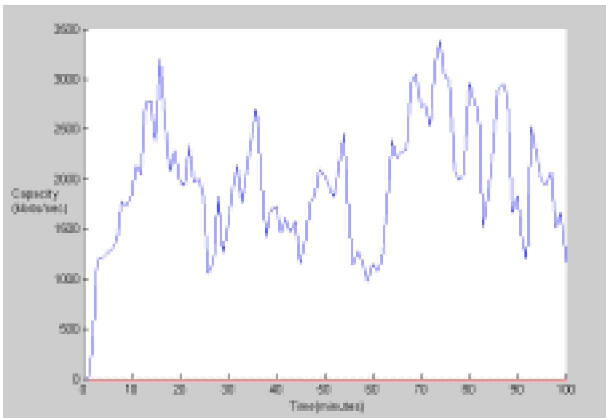

Figure 8 Traffic generated for a cell by simulation model.

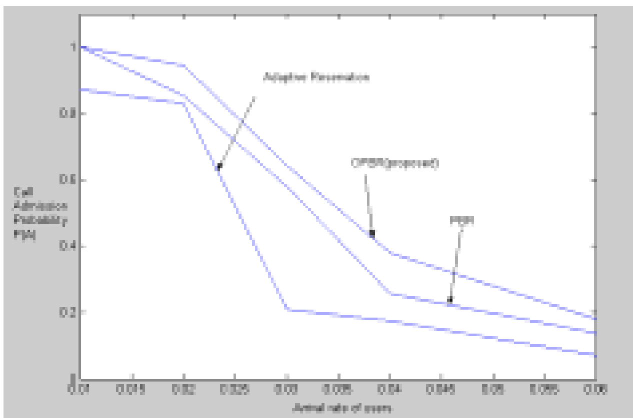

Figure 9 Call admission probability against the call arrival rate.

video calls.

The simulation time is 100 minutes and calls as per assumption are originated against the time as shown in Figure 8. For the purpose of comparison call admission probability is calculated for various schemes. The results shown in Figure 9 indicated higher values of call admission are achieved by the proposed scheme.

6 Conclusion

In this paper we proposed a call admission and bandwidth reservation scheme for future wireless networks. Analytical results have proved the effective bandwidth utilization and increased probability of call admission and handoff for the proposed scheme. This result in reduced new call rejection rate and premature termination of call due to unsuccessful handoff. The scheme has proved superior compared to some popular reservation based schemes [6,7].

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Biographies

Mehboob Alam currently M.Sc. student in the Department of Electrical and Computer Engineering at University of Calgary. His research interest includes VLSI signal processing, Communication and Wireless Network. He is recipient of iCORE International Graduate Scholarship.

Wael Badawy (Ph.D. 00, M.Sc 98, 97; B.Sc. 94)is an associate professor in the Department of Electrical and Computer Engineering. He holds an adjunct professor in the Department of Mechanical Engineering, University of Alberta.

Dr. Badawy's research interests are in the areas of: Microelectronics, VLSI architectures for video applications with low-bit rate applications, digital video processing, low power design methodologies, and VLSI prototyping. His research involves designing new models, techniques, algorithms, architectures and low power prototype for novel system and consumer products.

Dr. Badawy authors and co-authors more than 100 peer reviewed Journal and Conference papers and about 30 technical reports. He is the Guest Editor for the special issue on System on Chip for Real-Time Applications in the Canadian Journal on Electrical and Computer Engineering, the Technical Chair for the 2002 International Workshop on SoC for real-time applications, and a technical reviewer in several IEEE journals and conferences. He is currently a member of the IEEE-CAS Technical Committee on Communication. Dr. Badawy is honored with the "2002 Petro Canada Young Innovator Award", "2001 Micralyne Microsystems Design Award" and the "1998 Upsilon Pi Epsilon Honor Society and IEEE Computer Society Award for Academic Excellence in Computer Disciplines. He is currently the Chairman of the Canadian Advisor Committee (CAC) and Head of the Canadian Delegation on ISO/IEC/JTC1/SC6 "Telecommunications and Information Exchange Between Systems". Member, The Canadian Advisory Committee for the Standards Council of Canada - Subcommittee 29: Coding of Audio, Picture Multimedia and Hypermedia Information, and Canadian Delegate, The ISO/IEC MPEG standard committee. He is a voting Member on the VSI Alliance. He is also the Chair of the IEEE-Southern Alberta Society-Computer Chapter.

Graham Jullien Graham A. Jullien, (Fellow IEEE) was educated in the United Kingdom, receiving degrees, in Electrical Engineering, from the Universities of Loughborough, Birmingham and Aston (Ph.D., 1969). He was a student engineer and data processing engineer at English Electric Computers, UK, from 1961 to 1966, and a visiting senior research engineer at the Central Research Laboratories of EMI Ltd., UK, from 1975 to 1976. From 1969 until 2000 he was with the Department of Electrical and Computer Engineering at the University of Windsor, Ontario, Canada, where he held the rank of University Professor and was the Director of the VLSI Research Group. Since January 2001, he has been with the Department of Electrical and Computer Engineering at the University of Calgary, where he holds the iCORE Research Chair in Advanced Technology Information Processing Systems. He is a member of the Board of Directors of the Canadian Microelectronics Corporation (CMC) and is a member of the Steering Committee and Board of Directors of the Micronet Network of Centres of Excellence. He has published widely in the fields of Digital Signal Processing, Computer Arithmetic, Neural Networks and VLSI Systems, and teaches courses in related areas. He has served on the technical committees of many international conferences; he currently serves on the Editorial Board of the Journal of VLSI Signal Processing; and is a past Associate Editor of the IEEE Transactions on Computers. He hosted and was program co-chair of the 11th IEEE Symposium on Computer Arithmetic, was program chair for the 8th Great Lakes Symposium on VLSI, and was the technical program chair for the 1999 Asilomar Conference on Signals, Systems and Computers. He is general chair for the 2003 Asilomar Conference and general co-chair of the International Workshop on System-on-Chip for Real-Time Systems, Calgary, Alberta, 2003.