Neuro-fuzzy admission control in mobile communications systems

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8. Conclusions and Recommendations for Further Research

8.1. Conclusions

Wireless networks will continue to grow and may eventually become the most popular form of communications. One main advantage of wireless networks is the ability to provide connections anywhere, anytime. This realization will not come true until some of the current problems are solved. In this thesis, the bandwidth reservation and admission control problem was studied and a solution presented using Fuzzy and Neuro-Fuzzy logic. While much research has been done in the areas of admission control and bandwidth reservation, as well as fuzzy logic, only a few studies have focused on using fuzzy logic in order to solve admission control and bandwidth reservation problems. As has been shown throughout this thesis, the flexibility of a fuzzy logic designed solution allows one to develop an acceptable solution without having to restrict the complex nature of the problem and without requiring too costly an effort in collecting data. In
this thesis, a Neuro-Fuzzy admission controller was used to adapt to the unique characteristics of each radio cell in a mobile wireless network, in order to guarantee required grade of service.

In Chapter 2 the fundamentals of cellular networks were presented along with the current state of the art in cellular networks. It can be seen that as cellular networks have advanced the difficulties in dimensioning these networks have remained intrinsically related to the hand-over call blocking probability. In order to address this issue, this chapter has shown that extensive research has been conducted into Call Admission Control (CAC) schemes that will provide a better QoS through the reduction of hand-over blocking. However, it has been shown that the development of such schemes relies heavily on a detailed understanding of the parameters defining the network as well as the evolution of these parameters. Measuring the evolution of the defining parameters has been found (according to the reviewed literature) to be very difficult and impractical, thus making a deterministic (or crisp) solution highly unlikely.

In Chapter 3 an overview of fuzzy and Neuro-Fuzzy logic was discussed. Fuzzy logic allows the combination of many different inputs through simple methods to produce some desired output. Neural networks when combined with fuzzy logic allow the adaptation of the fuzzy logic controllers through supervised and un-supervised training.

In Chapter 4 the problem of connection admission control was investigated with fixed bandwidth reservation. Analytical approximations were shown to agree with simulation results for an ideal multi-rate (multi-service) cellular network. It was concluded that fixed bandwidth reservation is effective if the cell dwell time is relatively large compared to the call holding time and it was observed that the
use of fixed bandwidth reservation where the cell dwell time is comparable to the call holding time is not effective. Also, a sensitivity study was carried out to show the impact of changing the ratio of class loads on the blocking probabilities. It was also observed that the cell dwell time distribution has an impact on call blocking performance.

In Chapter 5 it was observed that to obtain maximum utilization in a multi-service mobile network, enough bandwidth should be reserved for the dominant class (the class with highest bandwidth requirement) if all class loads are equal. This observation holds when the total cell capacity is large compared to the dominant class. This observation was also shown to be true when three, four and five classes of traffic were used. When the dominant class bandwidth requirement approaches the total capacity of the cell, maximum utilization diverges from the maximum bandwidth requirement. In fact a limit study showed that this is generally true when the cell dwell time is much larger than the call holding time. It was also observed as in Chapter 4 that where there are small cells and a high handover rate, the effective utilization is small compared with the case for larger cells.

In Chapter 6, fuzzy logic was studied in the context of the wireless mobile network. A fuzzy logic controller was designed and simulated to perform adaptive bandwidth reservation. The results produced were encouraging, but a problem was identified in correctly tuning the fuzzy logic controller to the desired constraints. (This problem was pursued in Chapter 7, where a Neuro-Fuzzy controller was investigated). The Fuzzy controller was redesigned in Chapter 6 to take into account more information from the network, namely the mobile terminal’s velocity and the amount of bandwidth being used in surrounding cells. The results showed that the fuzzy controller is able to match
the results that fixed bandwidth reservation achieved, but at the same time giving the network designer more control over the admission policy into the network.

In Chapter 7, a Neuro-Fuzzy controller was developed to carry out adaptive channel reservation in micro-cellular networks with general cell dwell times and call holding times. The results presented in Chapter 7 showed that the NFC outperforms both dynamic connection admission control and fixed bandwidth reservation. Such results verify the hypothesis that one may design an effective CAC scheme with limited knowledge about the network. Two unique algorithms were also developed that automated the process of training the NFC. This makes the application of NFC much more useful in a real world scenario.

Summary of major findings

Chapter 4

- Adaptation of [ROB1996] model for the use of multi-service mobile network. This is a general result for the case where the cell sizes are large. It was determined that fixed bandwidth reservation is appropriate when the cell sizes are large. In other words, the mean cell dwell time is much greater than the call holding time.
- A Sensitivity study was carried out that showed the impact that the cell dwell time distribution has on call blocking performance is not significant for large cell dwell times and became more significant as the cells became smaller.
- First order approximation was obtained for a more accurate approximation of the analysis, this a general result that can be applied to the analysis model.

Chapter 5

- In Chapter 5 it was observed that to obtain maximum utilization in a multi-service mobile network, enough bandwidth should be reserved for the dominant class (the class with highest bandwidth requirement) if all
class loads are equal. This observation was also shown to be true when 3, 4 and 5 classes of traffic were used. This result was generalized for the case where the cell sizes were large and for any number of classes of traffic.

- It was also observed through analysis that when the dominant class bandwidth requirement approaches the total capacity of the cell, maximum utilization diverges from the maximum bandwidth requirement.

- It was also observed through analysis as in Chapter 4 that where there are small cells and a high handover rate, the effective utilization is small compared with the case for larger cells.

Chapter 6

- It was shown that a fuzzy logic controller is able to match the performance of adaptive channel reservation in Chapters 4 and 5. This was a simulated study with no analysis, but when the results of the two bandwidth reservation controllers are compared, the results are quite comparable, and there is nothing to suggest that fuzzy logic can’t be used in other forms of adaptive bandwidth reservation.

Chapter 7

- The results in Chapter 7 show that Neuro-Fuzzy controllers are able to ‘learn’ and adapt to the traffic conditions and quickly and effectively change the number of channels to be reserved in a mobile cell. While the results shown were for three different probability distributions, they cover a large spectrum and the results could be considered general. The probability distributions included Poissonian, Lognormal and Gamma distributions.

8.2. Recommendations for Further Research
Conclusions and Recommendations for Further Research

The use of Fuzzy Logic in telecommunications and especially mobile remains an open area of research. A number of specific issues are recommended for further exploration and research.

8.2.1. Neuro-Fuzzy Logic Controller in Multi-service Mobile Networks

In Chapter 7, a Neuro-Fuzzy controller was used to adaptively control the bandwidth required to guarantee the grade of service. It is a logical step to extend the work to form a multi-service Neuro-Fuzzy controller. The major problem that needs to be overcome here is the fact that Fuzzy Logic is not very scalable to the number of inputs, and hence an increase in the number of inputs due to multiple classes of traffic will be difficult to deal with.

One possible way to proceed would be to design the controller only for the most significant class of traffic. In Chapters 4 and 5 this was observed to be the class requiring the most bandwidth.

8.2.2. Mobility Model Selection

In this thesis mobile terminals were always assumed to move between cells with equal probability. The cell sizes were always considered equal in size and probability distributions. In Chapters 4 and 7, lognormal and gamma distributed cell dwell and call holding times were considered. It would be interesting to investigate whether Neuro-Fuzzy logic control is able to provide some advantage when the variables mentioned above are not uniform and vary from cell to cell.

8.2.3. Application to Current Wireless Network
In this thesis all schemes were applied in a general sense, i.e. only the high level characteristics were considered (for example, effective capacity). Current wireless local area networks have the ability to provide multi-service support with guaranteed QoS. The work in this thesis may be extended by applying it to a WLAN/WPAN scenarios based on IEEE 802.11 and IEEE 802.15.3 standards.