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Enhanced hop-limited handoff scheme for linear broadband cellular networks

K.S. Chan, S. Chan, K.T. Ko and Li Ping

An enhanced handoff scheme for ATM-based cellular networks in linear environments is proposed. Some regularly spaced cells are assigned as rerouting cells. If a handoff call comes to a rerouting cell, its traffic path is rerouted to a PVC between the cell and the ATM switch. If a handoff call comes to an ordinary cell, its traffic path is simply elongated by a PVC between the new cell and its previous cell. The path efficiency is improved.

Introduction: In ATM-based cellular networks, fast, seamless and distributed handoff is a crucial issue. The VCT scheme [1] requires an excessive amount of network resources. The processing load of a network would be too high in the SCMC scheme [2]. When the handoff frequency is high, the path efficiency would be low if the PVC-based scheme [3] were used. So, in [4], the hop-limited scheme is proposed for ATM-based cellular networks in planar environments. In this scheme, if the number of successive handoffs is less than a preset number, the traffic path is elongated by a PVC between the new cell and the current cell. If the number of successive handoffs reaches the preset number, the traffic path is rerouted to a PVC between the ATM switch and the new cell. By limiting the number of successive path elongations, the path efficiency can be improved and the processing load of the network can be kept light.

If the network is in a linear environment, we can further improve the performance. In the enhanced scheme, some cells are assigned to be special cells, others are ordinary cells. The special cells are regularly spaced. Only if the handoff call comes to a special cell would the traffic path be rerouted. If a handoff call comes to an ordinary cell, the traffic path simply would be elongated by a PVC between the new and current cells. Some multiplexing gain can be obtained by this scheme.

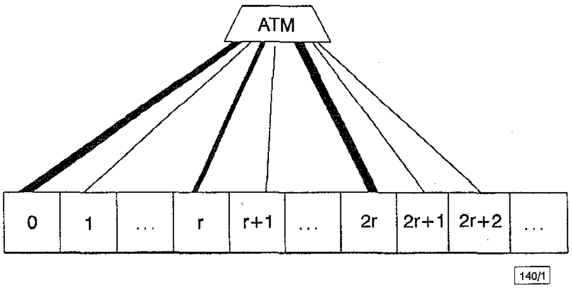

Fig. 1 *Network architecture in linear environments under the enhanced scheme*

━━ SVC + PVC
── SVC

Scheme description: We consider a linear ATM-based cellular network as shown in Fig. 1. All cells are connected to an ATM switch. Each pair of neighbouring cells are connected by a number of PVCs. Some cell are assigned to be special cells which are regularly spaced. Assume that the special cells are separated by $r - 1$ ordinary cells. There are SUCs and PVCs between a special cell and the ATM switch. There are only SVCs between an ordinary cell and the ATM switch. When a mobile makes a new call, its base station will establish an SVC to carry the new call. When the call is handoff to an adjacent cell and if the adjacent cell is a special cell, the traffic path would be rerouted to the PVC between the special cell and the ATM switch. Conversely, if the adjacent cell is an ordinary cell, the traffic path will be extended by a PVC from the current cell to the adjacent cell.

Now, we illustrate how the scheme operates by considering an example. Referring to Fig. 1, let the base station in cell i be denoted as BS_i. Assume $r = 4$. Cells 0, 4, 8, ... are special cells. When a mobile initiates a new call in cell 1, BS_1 will establish an SVC between itself and the ATM switch. Consider the mobile roaming to its neighbouring cell 2. The mobile first sends a handoff request message to the BS_2. Because cell 2 is an ordinary cell, a PVC between BS_2 and BS_1 is assigned to this call. Similarly, when the mobile goes on to visit cell 3, the traffic path is elongated by a PVC between BS_2 and BS_3.

Next, consider that the mobile goes on to visit cell 4. BS_4 is a special cell, a PVC between BS_4 and the ATM switch is assigned to this call, and the SVC between BS_1 and the ATM switch, PVCs between BS_1 and BS_2, BS_2 and BS_3 are all released.

Performance analysis: In this Section, we evaluate the performance of our scheme. Here, we consider voice calls only. The following assumptions are given first:

(i) The call holding time T_M is exponentially distributed with mean $1/\mu_M$.

(ii) The originating calls arrive in a cell following a Poisson process with rate λ_0.

(iii) The time interval R during which a mobile resides in a cell, called the cell sojourn time, has a general distribution. And the cell sojourn times, $R^{(1)}$, $R^{(2)}$, ..., consecutively induced by movement of a mobile are independent and identically distributed.

Consider a mobile in a cell. A VC connecting the cell's base station to the ATM switch or another cell's base station is occupied by the mobile. The VC can be released in three cases: (i) the connection is naturally terminated; (ii) the connection is forced to be terminated due to handoff blocking; (iii) the mobile is successfully handoff to a special cell; here we assume that the mobile has already resided in i cells when it roamed to the special cell. Let the time interval from the moment that the VC is occupied by the call to the moment that the VC is released due to any case listed above be T_i.

Let p_f be the probability that the call would be blocked due to unavailability of PVC when the mobile tries to handoff to another cell. For the assumption that R is exponentially distributed with mean μ_R, the mean of T_i is

$$E[T_i] = \frac{1 - \left[\frac{\mu_R(1-p_f)}{\mu_M+\mu_R}\right]^i}{\mu_M + p_f\mu_R}$$

Here, we assume that the mobile will only move along one direction. That is, if at first the mobile is moving from left to right, then throughout the call the direction of movement will not be changed.

Referring to Fig. 1, cell 0 is a special cell. Let n^s_{si} be the mean number of SVCs connecting the BS_i to the ATM switch ($0 \le i \le r - 1$); n^s_{pi} be the number of required PVCs connecting the BS_i to the ATM switch (if cell i is not a special cell, then $n^s_{pi} = 0$); n^n_{li} be the required number of PVCs connecting cell i to its left neighbour; n^n_{ri} be the required PVCs connecting cell i to its right neighbour (if cell i is a special cell, $n^n_{li} = n^n_{ri} = 0$). Now we will derive the required quantities.

To each cell, the handoff call arrival rate is

$$\lambda_h = \frac{\mu_R(1-p_n)\lambda_o}{\mu_M + \mu_R p_f}$$

where p_n is the blocking probability for new calls. If the probability that a handoff call is from the left neighbouring cell or from the right neighbouring cell is the same, then the handoff call arrival rate from left neighbouring cell is $\lambda_h/2$.

Now we will derive the mean number of SVCs in cell i ($0 \le i \le r - 1$) first. Consider cell i. If a call is initiated and accepted in cell i, an SVC will be occupied by the call. Now if the mobile moves to the left, at most after going through i cells, he will reach cell 0, which is a special cell. So the call will be rerouted and the SVC in cell i would be released. So the mean holding time is $E[T_i]$. If the user moves to the right, the mean holding time is $E[T_{r-i}]$. So we have

$$n^s_{si} = \lambda_0(1-p_n)(E[T_i]+E[T_{r-i}])/2 \qquad (1)$$

The average number of SVCs per cell is $N_1 = (\Sigma^{r-1}_{i=0} n^s_{si})/r$.

Now we derive the required number of PVCs for cell i to connect to its left neighbouring cell (cell $i-1$) n^n_{li}. If a mobile comes to cell i from cell $i-1$, then a PVC between these two cells will be occupied. In this case, the call arrival rate is $\lambda_h/2$ and the mean holding time is $E[T_{r-i}]$. So, we have

$$p_f = \frac{(\lambda_h E[T_{r-i}]/2)^{n^n_{li}}/n^n_{li}!}{\sum_{n=0}^{n^n_{li}}(\lambda_h E[T_{r-i}]/2)^n/n!} \qquad (2)$$

Conversely, if the mobile comes from cell $i+1$, the PVC's mean holding time is $E[T_i]$. So we have

$$p_f = \frac{(\lambda_h E[T_i]/2)^{n^n_{ri}}/n^n_{ri}!}{\sum_{n=0}^{n^n_{ri}}(\lambda_h E[T_i]/2)^n/n!} \qquad (3)$$

From eqns. 2 and 3, we can obtain n^n_{li} and n^n_{ri} for a specified p_f. The average number of required PVCs connecting to neighbouring cells per cell is

$$N_2 = \frac{\sum_{i=1}^{r-1}(n^n_{li}+n^n_{ri})}{r}$$

For cell 0, the required number of PVCs connecting to the ATM switch is denoted as n^s_{p0}. The handoff call arrival rate is λ_h and the mean holding time is $E[T_r]$. So we have

$$p_f = \frac{(\lambda_h E[T_r])^{n^s_{p0}}/n^s_{p0}!}{\sum_{n=0}^{n^s_{p0}}(\lambda_h E[T_r])^n/n!} \qquad (4)$$

The average number of required PVCs connecting to the ATM switch per cell is $N_3 = n^s_{p0}/r$.

Table 1: Required number of VCs for different schemes

	N_1	N_2	N_3	Total
PVC-based scheme	23.6	48	0	71.6
Original scheme, $r = 3$	20.6	36	10	66.6
Enhanced scheme, $r = 3$	16.7	23.3	12	52

Now we roughly compare our scheme with the PVC-based scheme [3] and the original hoplimited scheme [4]. Table 1 shows the required number of VCs for different schemes, given that the new call arrival rate is 11.9 calls per minute, the mean call holding time is 2 min and the mean cell sojourn time is also 2min. The new call blocking probability is 1% and handoff call blocking probability is 0.1%. It can been seen that both the original and enhanced hop-limited schemes require fewer VCs than the PVC-based scheme. When $r = 3$, the original and enhanced hop-limited schemes require 7 and 27% less, respectively, than that of the PVC-based scheme.

Conclusions: In this Letter, an enhanced hop-limited handoff scheme for linear broadband cellular networks is proposed. In this scheme, some cells are assigned to be special cells, and others to be ordinary cells. The special cells are regularly spaced. If a handoff call comes to a special cell, its traffic path is rerouted to a PVC between the special cell and ATM switch. If a call is handoff to an ordinary cell, its traffic path is elongated by a PVC between the new cell and previous cell. The traffic path efficiency is further improved over that of the PVC-based scheme.

24 October 1997

Electronics Letters Online No: 19980104

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Flowmeter for QoS provision in packet switched networks

Kicheon Kim and D. Hutchison

A flowmeter is a set of traffic-related variables associated with a connection established in a network node as a result of the connection setup. Comprehensive quality-of-service provision to each packet flow is the purpose of flowmeter-based dynamic packet scheduling. The earliest deadline first (EDF) scheduling algorithm is adopted for rate allocation, delay control, and flow control. A gas pressure admission control algorithm is also presented to simplify EDF admission test. The delay performance of the scheduler is evaluated on a subnetwork of the Internet.

Introduction: Since the fair queueing idea [1] was introduced, packet scheduling order has been of great concern [2, 3]. As the main parameter to determine the service order of fair queueing, virtual clock [4] and virtual time [5 – 7] have been proposed. A flowmeter is a set of traffic-related variables of a packet flow and an architectural extension of fair queueing. More comprehensive quality-of-service (QoS) provision is the main motivation of the extension. Major QoS parameters for multimedia communications are related to rate allocation, delay control, and flow control. Most fair queueing algorithms guarantee on demand rate allocation, but the delay bounds are fixed to the ratio of packet size to its reserved rate; low rate hard realtime traffic has a disadvantage. Flowmeter-based dynamic packet scheduling decouples the delay control from rate allocation and supports flow control in order to prevent overflow at the downstream buffer.

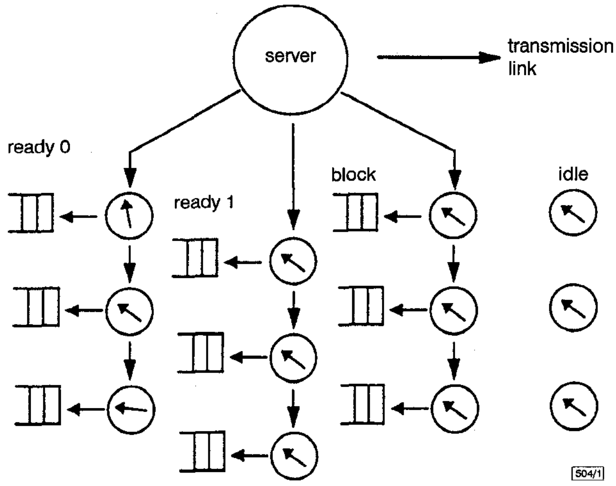

Fig. 1 *Flowmeter-based dynamic packet scheduling*

EDF scheduler: The traffic model for the earliest deadline first (EDF) scheduler is defined by rate, packetisation period, and transmission deadline: (ρ_i, T_i, D'_i), where $0 < D'_i \le T_i$. To accommodate the deadline scheduling, each connection's virtual clock is expressed by two virtual clock variables; transmission deadline $D'_{i,n}$, and virtual finishing time $F_{i,n}$. Flowmeters are sorted into increasing order of transmission deadlines as shown in Fig. 1 (ready0); the server picks a packet from the top flowmeter. For each connection i sharing the same transmission link C, the virtual clock variables of the arriving packets with length, $L_{i,n}$, are iteratively computed as follows: