Performance Evaluation of Fixed Channel Allocation Strategy with Handoff Reservation Policy for Velocity Dependent Dynamic Handoff Threshold

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***Abstract*-- In wireless cellular communication systems, channels are inadequate and hence should be utilized efficiently. In this paper, we have applied Fixed Channel Allocation (FCA) strategy for channel allocation in 81-cell system having uniform traffic. Square shape cells & cluster size of nine has been considered for the model, using GSM 1800 specifications. The model also considers fixed channel reservations (5% to 15% of total channel per cell) for handoff calls only to reduce the handoff call dropping probability (HCDP). Different call arrival rates (CAR) ranging from 0.1 calls/second to 4 calls/second have been considered. The paper uses velocity dependent dynamic handoff thresholding (VDDyHOT) mechanism. An appropriate analytical model has been devised to support simulation performance characteristics. The results of simulation and an analytical model indicate that the handoff dropping probability reduces with increase in percentage handoff reservation. Similarly, velocity based handoff boundary (threshold) helps in avoiding early handoffs, thus making handoff decisions at appropriate time. A comparison between HCDP with fixed threshold boundary for handoff and HCDP with velocity dependent dynamic threshold boundary for handoff has been attempted.**

***Index Terms*-- Channel allocation, priority schemes, analytical model, handoff reservation Nomenclature**

I. Introduction

In the FCA strategy a set of nominal channels is permanently allocated to each cell for its exclusive use. Here a definite relationship is assumed between each channel and each cell, in accordance to co-channel reuse constraints. The total number of available channels in the system is divided into sets. Each cell will have one set of channels, and number of set will be equal to the cluster size. In the simple FCA strategy, same numbers of nominal channels are allocated to each cell. This uniform channel distribution is efficient if the traffic distribution of the system is also uniform. In that case, the overall average blocking probability of the mobile system is the same as the call blocking probability in a cell. Traffic in cellular systems can be non-uniform with temporal and spatial fluctuations, hence a uniform allocation of channels to cells may result in high blocking in some cells, while others might have a sizeable number of spare channels. [1] This could result in poor channel utilization. It is therefore appropriate to adapt the number of channels in a cell to match the load in it by using Dynamic Channel Allocation (DCA) and/or Hybrid Channel Allocation (HCA). Although the DCA & HCA schemes can adapt channel assignment to dynamic traffic loads, it can also significantly increase network complexity due to co-channel cell locking and signaling overheads, because it is a call-by-call based assignment. In order to keep both co-channel interference and adjacent channel interference under a certain threshold, cells within the required minimum channel reuse distance from a cell that borrows a channel from the central pool cannot use the same channel. DCA also requires fast real-time signal processing and associated channel database updating.[2] In this paper uniform traffic is assumed hence FCA technique is used.

This paper focuses on handling handoffs. In general, the handoff event is caused by the radio link degradation or initiated by the system that rearranges radio channels in order to avoid congestion. In this paper the focus is given on the first kind of handoff, where the cause of handoff is poor radio quality due to a change in the environment or the movement of the wireless terminal. The mobile subscriber is crossing the cell boundary, while the call is in process, the call must be handed off to the neighboring cell in order to provide uninterrupted service to the mobile subscriber. If adjacent cells do not have enough channels to support the handoff, the call is forced to be dropped. An important issue is to limit the probability of forced call termination, because from the point of view of a mobile user forced termination of an ongoing call is less desirable than blocking a new call. Therefore, the system must reduce the chances of unsuccessful handoffs by reserving some channels explicitly for handoff calls.

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Handoff prioritizing schemes provide improved performance at the cost of reduction in the total admitted traffic, in turn an increase in the blocking probability of new calls. The simplest way of giving priority to handoff calls is to reserve some channels explicitly for handoff calls in each cell [3]. This scheme is referred to as the *cutoff prior*ity *scheme (CPS)* or the *guard channel scheme*. Other prioritizing schemes allow either the handoff to be queued or new calls to be queued until new channels are obtained in the cell. The guard channel concept can also be used in DCA & HCA schemes. Here guard channels are not assigned to cells permanently; instead, the system can keep a collection of channels to be used only for handoff requests, or have a number of flexible channels with associated probabilities of being allocated for handoff requests. Relevant work and Problem Definition is discussed in Section II, Analytical Model is discussed in Section III, Section IV discusses Simulation Model, Results and Conclusion is discussed in Section V & VI respectively.

II. RELEVANT WORK AND PROBLEM DEFINITION

Generally size of cells is not same and various decisions regarding Absolute Radio Frequency Channel Numbers (ARFCN) allotment are made on practically gathered data. Algorithm discussed in [4] is best suited under these conditions. The improvement in the blocking probability of the heavy loaded cell is studied as a function of the arrival rate of the low traffic cell. In the light of this work and depending upon the structure of a particular network an optimum way can be found to allot the channels to various cells or to reshuffle them. Adjacent channel interference is another important parameter, which needs to be considered in grouping the channels with the proposed scheme. Still this scheme needs some modification as proposed in [4]. An Evolutionary Strategy (ES) is developed in [5], which optimizes the channel assignment. ES based algorithm has the advantage of producing reliable solutions in a smaller number of call generation as compared to other heuristics such as genetic algorithm. A novel hybrid channel assignment based scheme called D-ring is developed in [5]. The advantage of the representation proposed in [5] over the others is that it reduces the computation time involved in the calculation of the energy when the demand of channel is less than the total number of available channels. Using concept of neighboring area reduces the time required in the determination of co-channel interference. Lot of research has been done in this area but thought for velocity dependent handoff thresholding is give here. Fast moving calls, when enter into handoff area will get less time for handoff processing compared to slow moving calls, which may cause forced termination of fast moving calls. This can be avoided by making handoff threshold value dynamic with velocity of calls. Every call will get equal amount of time for handoff processing. Handoff process will be initiated early for fast moving calls whereas for slow moving handoff will begin little later in contest with the distance from lower threshold value for cell. In short for fast moving calls handoff threshold value (distance) will be comparatively larger than for slow moving calls. A comparison between HCDP with fixed threshold boundary for handoff and HCDP with velocity dependent dynamic threshold boundary for handoff has been attempted.

III. ANALYTICAL MODEL

A system with multiple cells is considered and all cells are homogeneous. Each of these cells has S channels. The channels holding time has an exponential distribution with mean rate μ. Both originating and handoff calls are generated in a cell according to Poisson process, with mean rate λ_O and λ_H respectively. [6] An analytical model for single cell is worked out here. Newly generated calls in cell of interest are labeled as originating calls. A handoff request will be generated when a channel holding Mobile Device approaches the cell of interest from its neighboring cell with signal strength below the handoff threshold. Priority is given to handoff call request by assigning S_R channels exclusively for handoff calls among the S channels in a cell. The remaining S_C $(=S - S_R)$ channels are shared by both originating calls and handoff requests. An originating call is blocked if the number of available channels in the cell is less than or equal S_R $(= S - S_C)$. A handoff request is blocked if no channel is available in the target cell. The system model is shown in Fig.1. The system model is modeled as M/M/S/S queuing model.

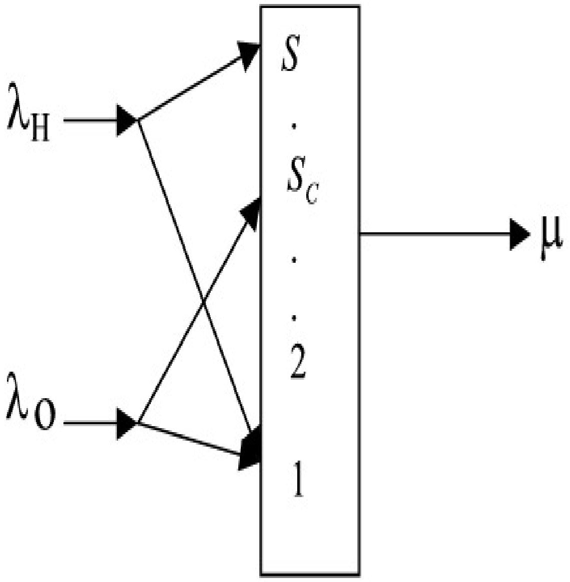


Fig. 1. System model with priority for handoff calls

State transition diagram for the Fig.1. is shown in Fig.2. The state ***i (i = 0, 1,---,S)*** of the cell is defined as the number of calls in progress that cell. Let ***P(i)*** represents the steady-state probability that cell is in state ***i***.[7][8] The probabilities ***P(i)*** can be determined in the usual way for birth-death processes.

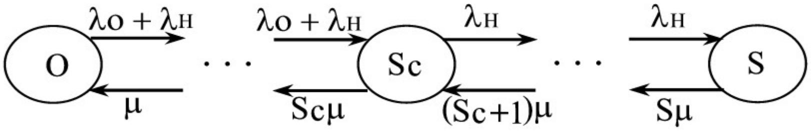


Fig. 2. State transition diagram

From state diagram shown in Fig. 2, the state equilibrum equations are written as in

$$i\mu P(i) = (\lambda_0 + \lambda_H)P(i-1) \qquad 0 \le i \le S_C$$
$$i\mu P(i) = \lambda_H P(i-1) \qquad S_C \prec i \le S \qquad \ldots 1$$

Using these equations recursively along with normalized condition

$$\sum_{i=0}^{S} P(i) = 1 \qquad \ldots 2$$

The steady state probability P(i) is expressed by

$$P(i) = \begin{cases} \dfrac{(\lambda_0 + \lambda_H)^i}{i!\,\mu^i} P(0) & 0 \le i \le S_C \\[2ex] \dfrac{(\lambda_0 + \lambda_H)^{S_C} \lambda_{H^{i-S_C}}}{i!\,\mu^i} P(0) & S_C \le i \le S \end{cases} \qquad \ldots 3$$

Where P(0) value is

$$P(0) = \left[\sum_{i=0}^{S_C} \frac{(\lambda_0 + \lambda_H)^i}{i!\,\mu^i} + \sum_{i=S_C+1}^{S} \frac{(\lambda_0 + \lambda_H)^{S_C} \lambda_H^{i-S_C}}{i!\,\mu^i} \right]^{-1} \qquad \ldots 4$$

The blocking probability Pb for an originating call is given

$$Pb = \sum_{i=S_C}^{S} P(i) \qquad \ldots 5$$

The blocking probability Pd of a handoff request is given

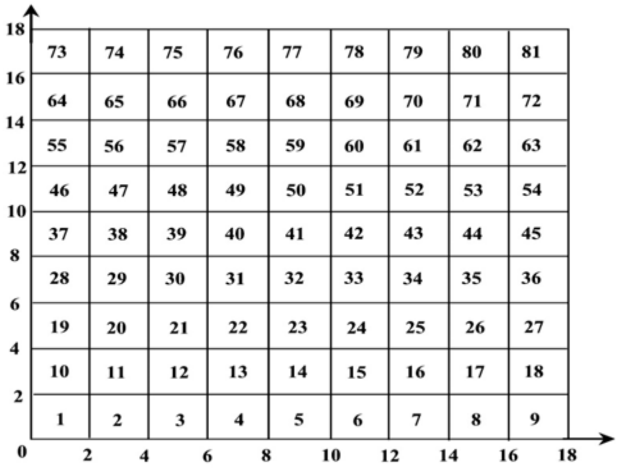
$$Pd = P(S) = \frac{(\lambda_0 + \lambda_H)^{S_C} \lambda_H^{S-S_C}}{S!\,\mu^S} P(0) \qquad \ldots 6$$

IV. SYSTEM SIMULATION

A. Simulation Model

Unlike other simulations, which consider one or two cells, this model is developed for 81 cells, shown in Fig. 3. All 81 cells are divided into 9 clusters each of 9 cells. Modeling is done with Manhattan city pattern as is considered for metro cities. The area of each cell is 2 X 2 km^2. It is assumed that the top cells (cells 73 –81) and the bottom cells (cells 1-9) are connected (wrap around). That is if a user goes out of cell 73 from top, he will enter into cell 1. Analogously, it is assumed that the left cells (cell 1,10 19…73) and right cells (cell 9, 18, 27 …81) are connected too [9]. Two operators are considered in service area, which will provide 186 carriers for single cluster. One carrier per cell is reserved for control signals. Remaining carriers are distributed into 9 cells. Every cell will have around 20 carriers. 5%, 10% or 15% carriers from each cell are kept reserved exclusively for handling handoff calls. Each carrier is further divided into 8 time slots. This carrier – slot distribution is replicated for all 9 clusters.

Fig. 4 shows the concept of handoff-threshold and receive-threshold setting. Assume the base station of each cell is at the center of the square; the receive-threshold is set to 1.414km in order to cover all cell area.



73	74	75	76	77	78	79	80	81
64	65	66	67	68	69	70	71	72
55	56	57	58	59	60	61	62	63
46	47	48	49	50	51	52	53	54
37	38	39	40	41	42	43	44	45
28	29	30	31	32	33	34	35	36
19	20	21	22	23	24	25	26	27
10	11	12	13	14	15	16	17	18
1	2	3	4	5	6	7	8	9

Fig. 3. Simulated wireless network

The handoff threshold can be set at any distance between cell-center to receive-threshold. The area between handoff threshold and receive-threshold is called handoff-area (the shaded area in Fig. 4). The handoff threshold value has been considered with two different ways. A fixed handoff threshold set at 1.314 km. If a mobile user moves at even maximum speed (for metro cities maximum speed is assume at 15 meter/sec), user will have 6 seconds for handoff before moving out of this handoff area. Where as the average speed of the user is considered of 7mtr/sec, with this speed user will get 14 seconds time in handoff region. Other consideration for handoff threshold is mobile device’s velocity dependent. Slow moving devices will get maximum time for handoff processing in fixed threshold, whereas fast moving devices will get little time. This may cause termination of calls, which are attempting handoff. Velocity dependent handoff threshold will overcome this problem. In this method every call will get equal time for handoff process, say 10 seconds. Eventually fast moving mobile devices will start handoff process at longer distance from cell boundary, whereas slow moving will start handoff process relatively closer to the cell boundary. The user mobility pattern is described as follows. When a new call request is accepted for a cell, the call originating location of the mobile user is a uniform random variable of that particular cell, and the moving direction is set by a uniform random angle between o° and 360°. The moving speed is uniformly distributed between 3.6 Km/hr to 55Km/hr. User's location and Received Signal Strength (RSS) has been monitored at every second. The simulation is carried out for 5000 seconds for call arrival rate (CAR) is varied in two intervals. First from 0.1 calls per second per cell to 1 call per second per cell with the step of 0.1, and Second from one call per second per cell to 4 calls per second per cell with the step of 1.

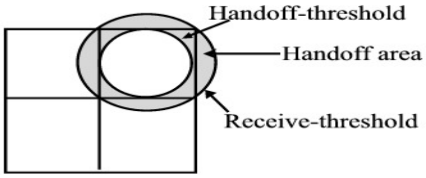


Fig. 4. Handoff threshold and receive threshold

B. System Flowchart

Flow chart of the system is shown in Figure. 5. Non-availability of carrier-slot in the cell of interest drops a new call request. After a new call is accepted, the call completion is monitored. The call will be terminated if its duration is completed, and resources will be released. If call is continuing, it's RSS level will be monitored. If RSS level is lower than Handoff threshold (which will be calculated based on the velocity of call) then this call will be handoff to target cell. If carrier slots from general pool are not available then a carrier slot from handoff-reserved pool is used for handoff call, otherwise a call is dropped if its RSS level is lower than the Lower threshold value of RSS.

V. RESULTS

As discussed in earlier section the simulation is carried out for 5000 seconds time for specified CAR. During this simulation time total 5,00,000 calls are simulated. At lower traffic values, i.e. CAR from 0.1 calls/second to 1 call/second the system performance is at its peak. Fig. 6 shows comparison ***BP*** values of analytical model and simulation model with fixed handoff threshold, whereas the ***DP*** comparison is shown in Fig. 7. The ***BP*** values for fixed handoff threshold (FHOT) and that for velocity dependent dynamic handoff threshold (VDDyHOT) are same. This performance comparison is plotted in Fig. 8. ***BP*** values are zero until the CAR is1 call/second, whereas for CAR 2 to 4, BP values for different handoff reservation percentage are given in Table I. Handoff call ***DP*** values for both schemes i.e. FHOT & VDDyHOT, for different handoff reservation percentage are indicated in Table II. Fig. 9 shows the performance of handoff call dropping probabilities for FHOT and VDDyHOT for different values of handoff reservation. The difference between these values is too small to distinguish the effect in plot. Table III shows the percentage change in dropping probabilities for FHOT to VDDyHOT. Table IV shows percentage change in ***DP*** for 5 % handoff reservation to 10 % reservation, and 5% to 15%, similarly Table V gives the values for VDDy for different percentage of handoff reservation.

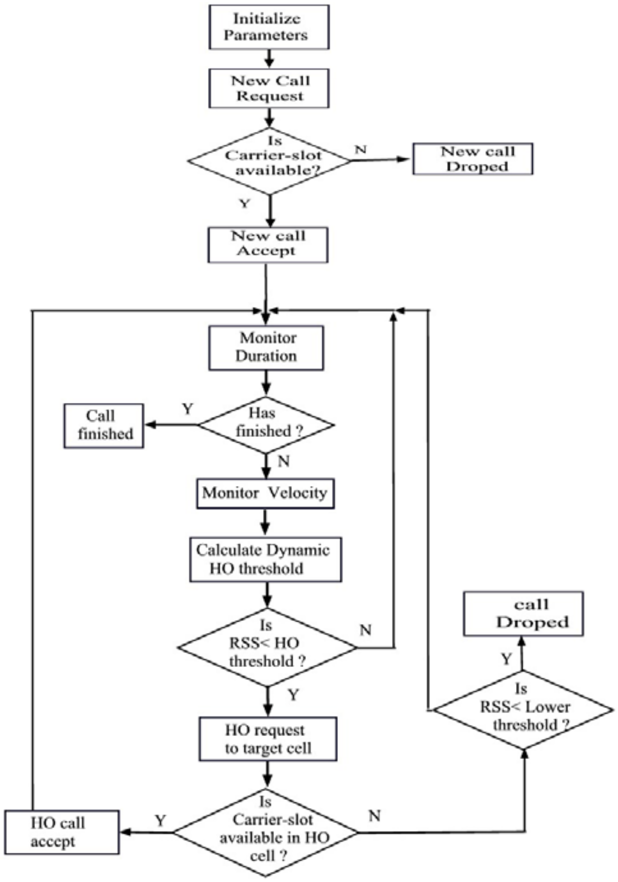


Fig. 5. Flow chart of the System

VI. CONCLUSION

The results of simulation and an analytical model indicate that the handoff dropping probability reduces with increase in percentage of priority channels. Similarly, velocity based handoff boundary (threshold) helps in avoiding early handoffs, thus making handoff decisions at appropriate time. A comparison between HCDP with fixed threshold boundary for handoff and HCDP with velocity dependent dynamic threshold boundary for handoff has been attempted. Dropping Probabilities values drastically reduces in both schemes when percentage of handoff channel reservation is changed from 5 percent to 10 percent, whereas this reduction is comparatively small when handoff reservation is changed from 10 percent to 15 percent.

TABLE I:
PERFORMANCE COMPARISON OF BLOCKING PROBABILITIES OF
FIXED HO THRESHOLD WITH VDDY HO THRESHOLD

% Of HO Reservation	Scheme	CR = 1	CR = 2	CR = 3	CR = 4
5 %	Fixed	0	0.2382	0.4775	0.6053
	VDDy	0	0.23798	0.47748	0.60511
	Analytical	0	0.1903	0.3455	0.5498
10 %	Fixed	0	0.27353	0.50316	0.62486
	VDDy	0	0.27354	0.50296	0.62473
	Analytical	0	0.2007	0.4009	0.6349
15 %	Fixed	1.7284e-006	0.30947	0.52881	0.6445
	VDDy	2.963e-006	0.30925	0.52864	0.64436
	Analytical	0.0001	0.2172	0.4667	0.7289

TABLE II
PERFORMANCE COMPARISON OF DROPPING PROBABILITY OF
FIXED HO THRESHOLD WITH VDDY HO THRESHOLD

% Of HO Reservation	Scheme	CR = 1	CR = 2	CR = 3	CR = 4
5 %	Fixed	0	0.0037	0.017055	0.0222
	VDDy	0	0.0036665	0.0169	0.022191
	Analytical	0	4.7333e-005	0.0019985	0.010629
10 %	Fixed	0	4.5541e-005	0.00061996	0.0010472
	VDDy	0	4.249e-005	0.00060812	0.0010197
	Analytical	0	4.4704e-006	0.00019476	0.0011494
15 %	Fixed	0	2.1432e-006	4.8905e-006	1.0417e-005
	VDDy	0	1.6081e-006	4.3676e-006	9.3734e-006
	Analytical	0	4.2277e-007	1.9287e-005	0.00012866

TABLE III
% CHANGE IN PERFORMANCE OF FIXED HO
THRESHOLD WITH VDDY HO THRESHOLD

% Of HO Reservation	CR = 2	CR = 3	CR = 4
5 %	0.905	0.908	0.041
10 %	6.699	1.9098	2.6261
15 %	24.96	10.69	10.01

TABLE IV
% CHANGE IN PERFORMANCE OF FIXED HO
FOR DIFFERENT HO RESERVATION

% Of HO Reservation	CR = 2	CR = 3	CR = 4
5 % - 10 %	98.76	96.36	95.2829
5 % - 15 %	99.94	99.97	99.95

TABLE V
% CHANGE IN PERFORMANCE OF VDDY HO
FOR DIFFERENT HO RESERVATION

% Of HO Reservation	CR = 2	CR = 3	CR = 4
5 % - 10 %	98.84	96.40	95.40
5 % - 15 %	99.95	99.97	99.95

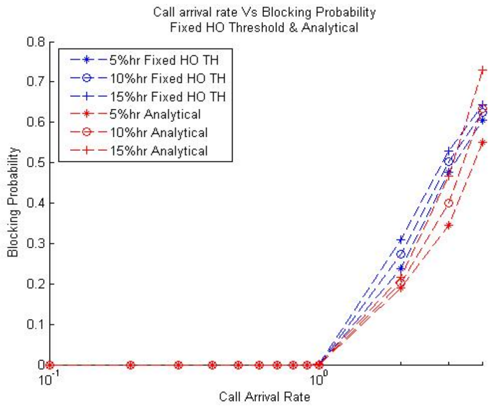


Fig.6.Blocking Probability of Analytical Model and FHOT

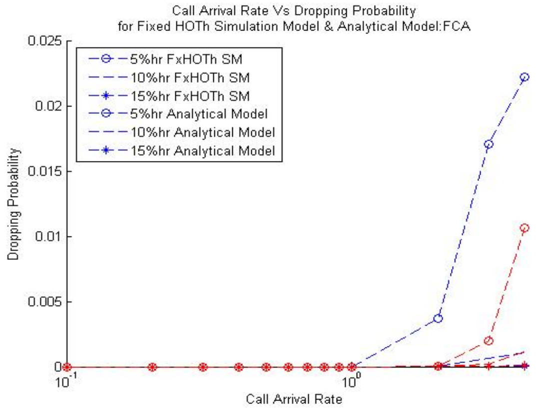


Fig.7. Dropping Probability of Analytical Model and FHOT

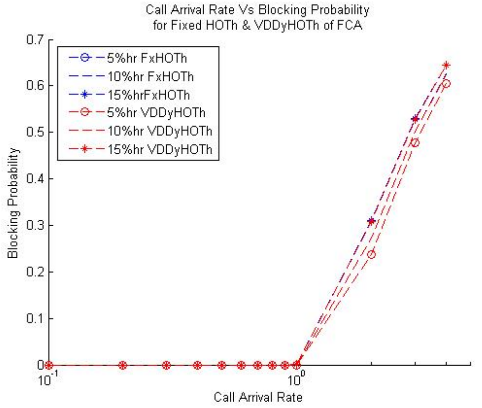


Fig.8.Blocking Probability of FHOT & VDDyHOT

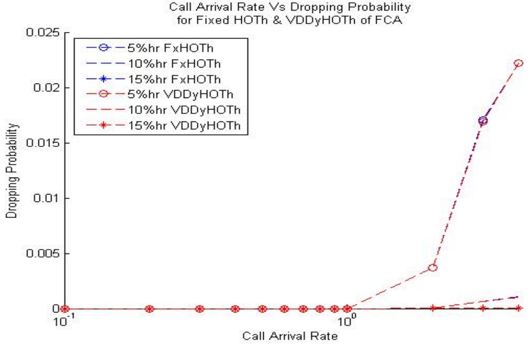


Fig. 9. Dropping Probability of FHOT & VDDyHOT

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VIII. BIOGRAPHIES

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